DESIGN OF CONTROLLER FOR REDUCTION OF TRACTOR SEAT VIBRATIONS DURING TILLAGE

A Thesis

Submitted in partial fulfillment of the

Requirements for the

Award of the degree of

DOCTOR OF PHILOSOPHY

in

Mechanical Engineering

By

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LOVELY PROFESSIONAL UNIVERSITY

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PUNJAB

(2024)

DECLARATION

I declare that the thesis entitled **"Design of Controller for Reduction of Tractor Seat Vibrations during Tillage"** has been prepared by me under the guidance of **Dr. Munish Mehta**, Professor, School of Mechanical Engineering, Lovely Professional University Phagwara, Punjab. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

I certify that **Harbhinder Singh** bearing Registration No. **41800960** has prepared his thesis entitled **"Design of Controller for Reduction of Tractor Seat Vibrations during Tillage"** for the award of PhD degree of Lovely Professional University, is a record of bonafide research carried out by him under my guidance and supervision. He has carried out the work at the School of Mechanical Engineering, Lovely Professional University. To the best of my knowledge the work incorporated in this thesis has not been submitted to any other University or Institute for the award of any other degree.

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ABSTRACT

Tractors have emerged as pivotal assets in modern agriculture, yet they pose challenges in terms of operator comfort due to undesirable vibrations. These vibrations not only affect the comfort, safety, and health of the operator but also jeopardize the integrity and performance of mechanical systems. Consequently, mitigating these vibrations is imperative to safeguard both machinery and personnel. Addressing this concern, conventional methods have been employed, but contemporary techniques such as controllers offer promising solutions. By operating within closed-loop circuits, controllers respond to input excitation forces to yield output signals, thus effectively managing vibrations. In the realm of agricultural machinery, particularly tractors, ensuring maximum operator comfort during prolonged fieldwork sessions remains a paramount design objective for manufacturing industries. A comprehensive study was undertaken to analyze vibrations transmitted at the base of the operator's seat, revealing predominant low-frequency vibrations, typically below 10 Hz. Notably, frequencies between 4 Hz to 6 Hz are particularly hazardous as per international standards, necessitating focused intervention. The study aimed to collect vibration data from the operator's seat, analyze it, and develop a Fuzzy-PID controller to attenuate vibration levels, thereby enhancing operator comfort during tillage activities. Raw experimental data on seat acceleration were obtained by varying tractor speed and utilizing different tillage implements. Subsequently, a validated model of the tractor-implement system was established. The proposed Fuzzy-PID controller is tailored to optimize operator ride quality by effectively mitigating vibrations. Comparative analysis with conventional PID systems and passive methods underscored the superior efficacy of the Fuzzy-PID approach in dampening vibration amplitudes at the driver's seat. To further assess the performance of this controlled suspension system, a simulation approach was employed, affirming the effectiveness and reliability of the proposed solution. This comprehensive study not only underscores the significance of vibration control in agricultural machinery but also showcases the efficacy of advanced control techniques in enhancing operator comfort and system performance.

ACKNOWLEDGEMENT

To commence with, I pay my obeisance to God, the Almighty to have bestowed upon me good health, courage and inspiration. Next I express my sincere and deepest gratitude to my supervisor **Dr. Munish Mehta** for providing precious guidance inspiring discussions and constant supervision throughout the course of this work. His expertise, invaluable guidance, constant encouragement, affectionate attitude, understanding and healthy criticism added considerably to my experience. His timely help and conscientious efforts made it possible to present the work contained in this thesis.

I would like to **Lovely Professional University** for giving me opportunity to carry out this research work. I am also grateful to Panjab University Chandigarh and PEC University of Technology for their support and cooperation during my experimentation.

I would like to thank my panel members who provided valuable suggestions during the course and all the staff members of School of Mechanical Engineering who have been very patient and cooperative during this work. A big thanks to all those who were directly or indirectly involved in the research work.

Finally I feel great happiness in expressing my deep sense love and thanks to my wife Dr.Tejbir Kaur and children Japanjot Kaur and Sehaj Amrit Singh for their incomparable mental support, patience and encouragement throughout my degree.

Harbhinder Singh

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NOMENCLATURE

Symbol	Description
F_{f_1},F_{f_2}	force transferred to the front left and right corner of the tractor chassis (N)
F_{r_1},F_{r_2}	tractor chassis's rear left and right corners experienced force (N)
K_{tf},K_{tr}	tractor's front and rear tyre stiffness (N/m)
z_{uf1}, z_{uf2}	the tractor chassis's front left and right corners' vertical displacement (m)
Z_{ur1}, Z_{ur2}	Tractor chassis's rear left and right corner's vertical displacement (m)
Z_{Rf1}, Z_{Rf2}	Ground's vertical undulation beneath the tractor's front left and right wheels (m)
Z_{Rr1}, Z_{Rr2}	Under the rear left and right wheels of the tractor, there is a vertical ground undulation (m).
c_{tf},c_{tr}	Tractor wheel damping ratios, front and rear (N-m/s)
Z_{cg}	tractor's vertical linear acceleration in the Z vector (m/s^2)
m_b	Tractor body mass (kg)
I_{XXt}	Tractor mass moment of inertia about X axis (kg-m^2)
θ	pitch angular acceleration (rad/sec2) of the tractor body during motion
l_f , l_r	dimensions specifying the position of the centre of gravity from the front and rear of the chassis (m)
$\emptyset$	Roll angular acceleration of tractor body during tractor movement (rad/s^2)
I_{yyt}	Tractor body mass moment of inertia about the Y axis (kg-m^2)
t_1, t_2	The dimensions of the tractor indicate its centre of gravity with respect to the left and right sides of the chassis (m).

ABBRIVATIONS

Abbreviations	Description
CG	Centre of gravity
DOF	Degree of freedom
RMS	Root mean square
PSD	Power spectral density
WBV	Whole body vibration
HAV	Hand arm vibration
KSS	Karolina drunkenness scale
CI	Comfort index
IRI	International roughness index
FFT	Fast Fourier transformation
DRI	Discrete roughness index
APAC	Alternating pressure air cushion

CHAPTER 1 INTRODUCTION

Agricultural mechanization has significantly transformed farming practices worldwide, enhancing efficiency, productivity, and sustainability. Among the most crucial innovations in this domain, tractors play an essential role in soil preparation, planting, and harvesting operations. However, despite advancements in technology, the comfort and well-being of tractor operators remain a pressing concern, particularly due to prolonged exposure to mechanical vibrations.

Vibration exposure in agricultural vehicles primarily stems from irregular terrain, ground conditions, and machine operation, which result in whole-body vibrations (WBV) and hand-arm vibrations (HAV). Prolonged exposure to these vibrations has been identified as a major occupational hazard, contributing to various health risks such as musculoskeletal disorders, lower back pain, fatigue, and even long-term neurological impairments. The European Parliament and Council's Directive 2002/44/EC [1] explicitly highlights the risks posed by mechanical vibrations to operators' health and safety, emphasizing the need for effective mitigation strategies.

Tractor operators are uniquely susceptible to vibration-related health issues due to the challenging working conditions they encounter. In many agricultural regions, including countries like India, where a large portion of the economy depends on farming, operators spend extended hours driving tractors over rough and uneven surfaces [2]. Despite the rising demand for tractors and advancements in their design, most models still lack dedicated suspension systems. Instead, they rely solely on the damping effect of tires to reduce vibration amplitudes, which is often inadequate.

The challenge of improving operator comfort goes beyond merely reducing vibrations; it requires an in-depth understanding of how vibrations are transmitted through vehicle structures, seating systems, and operator posture. Vibrations travel from the tractor's chassis to the seat and footrests, where they are transferred to the human body. Studies indicate that excessive exposure to these vibrations not only deteriorates spinal health but also affects cognitive performance, leading to decreased productivity and increased fatigue [3- 5]. To address these concerns, industry and academia have sought innovative solutions, particularly through the development of semi-active and active suspension systems aimed at improving vibration attenuation.

In recent years, research has focused on optimizing tractor seating systems and suspension technologies to enhance ride comfort. Ride comfort is influenced by multiple factors, including vibration magnitude, frequency, exposure duration, and the biomechanical response of the human body [6]. The International Organization for Standardization (ISO 2631-1:1997) and British Standard BS 6841 provide guidelines for measuring body vibrations and defining acceptable exposure limits. However, there remains a need to integrate these standards into practical and cost-effective design improvements for agricultural machinery [7-8].

This study aims to explore and develop advanced vibration control strategies to enhance tractor seat comfort and operator well-being. By investigating the transmission of vibrations, their physiological and psychological effects, and potential mitigation techniques, this research seeks to contribute to the evolution of ergonomic tractor design. The focus will be on evaluating different suspension systems, including semi-active and fuzzy logic-controlled suspensions, to determine their effectiveness in minimizing harmful vibrations.

Through a multidisciplinary approach combining biomechanics, engineering, and ergonomics, this research aspires to bridge the gap between theoretical studies and practical applications, ultimately fostering safer and more comfortable working conditions for tractor operators. The following chapters will delve into the detailed motivation behind this study, highlighting the necessity of technological advancements in agricultural vehicle design to improve the health and productivity of operators.

1.1 Overview of Vibrational Comfort

To achieve driver pleasure while driving a vehicle, ride comfort is a basic requirement; in fact, because ride comfort plays an important part in vehicle construction and market assessment, various research have been conducted to identify aspects that influence ride quality. Seating comfort in an agricultural vehicle is related to several elements, including dynamic, visual, and postural comfort. Vibrational stimulation is a significant contributing factor to driver comfort in agricultural vehicles.

Vibration is described as a mechanical movement that oscillates around a fixed point. Thus, it is a type of mechanical wave that can transport energy but not matter [9-11]. In terms of the nature of the vibration transmission phenomenon, the wave requires a mechanical structure, such as a machine, a vehicle, a tool, or even a human body, to travel through the surrounding space. Certainly, having defined vibration as a mechanical oscillation about a fixed reference point, it is vital to acknowledge that the human body is subjected to complicated waveforms, which are represented as a sum of sine waves. The transmission of vibration to the human body have psychological and physiological implications; in addition to motion sickness, it influences the individual's comfort, performance, and health.

Vibrations are transferred to tractor drivers by contact or sound as a result of high-speed driving, particularly on rough surfaces of fields. As a result, the frequency spectrum is divided into two categories: ride (0-25 Hz) and noise (25-25000 Hz). Vibrations common to all motor vehicles are typically in the 25 Hz to 25000 Hz range, which corresponds to the lower and higher hearing threshold frequencies [12].

1.2 Vibration Sources

The many types of excitation that create vibrations in the vehicle can be classified into two categories: indirect and direct excitations. Road roughness, ground conditions, and surface irregularities are examples of indirect excitations, whereas vibrations caused by automotive parts such as the engine and tyre assembly are considered direct causes of excitation.

The ground or pavement conditions are thought to be key sources of indirect excitation that cause vibrations, particularly in tractors. Surface roughness, in general, is a key cause of vibration in vehicles that operate on the ground via the tyre and wheel assembly. The engine and driveline system should be regarded a direct source of vibration. Moving parts that are not precisely balanced in the vehicle produce exciting forces during rotation and harmonics as a result of periodic disturbances that degrade drivability and comfort.

1.3 Classification of Vibration

The response of humans to vibration is a multidisciplinary subject that involves biology, psychology, engineering, and biomechanics. Human vibration is typically classified as hand-transmitted vibration, whole-body vibration (WBV) and motion sickness. When frequencies are less than 1 Hz motion sickness is concerned. WBV is largely associated to frequencies from 1 to 100 Hz, whereas hand transmitted vibration involves frequencies in the range of 08 - 1000 Hz.

Whole-body vibration happens when a human is held by a shaking surface and the vibration affects body areas far away from the source of exposure. Humans are more sensitive to whole-body vibrations at frequencies ranging from 1 to 20 Hz. However, because to the potential impact of WBV stimulation on individual comfort, performance and health, drivers' health and comfort have received special consideration [13-15].

In the automotive field of study, vibration is typically conveyed from the vehicle chassis to the driver support surfaces such as the seat and footrests. Vibration is conveyed from the seat to the driver's body and head. The gearbox path includes the driver's seat, vehicle surface, and body parts, which could lead to injury. Actually, because comfort and health are related in many ways, the method for calculating the health consequences in the automotive area is the same as analysing comfort.

Hand-arm vibration (HAV) occurs when a person grips a vibrating tool, such as a hand-drill machine or a car steering wheel. Drivers of passenger cars and commercial vehicles are also impacted by HAV. To lower the incidence of HAV-related health hazards, low-vibration emission tools may be designed and employed.

Because of the present patterns of adopting less sophisticated health and safety cultures at workplaces in the developing countries. Many people are susceptible to vibration hitches. Hand-transmitted vibration is frequently reported in people who use vibrating instruments, resulting in bone and joint, neurological, and muscle diseases. HAV-related illnesses can be separated into two categories: vascular and nonvascular [16], which are together known as hand-arm vibration syndrome or HAVs.

1.4 Effect of Vibrations

1.4.1 Health Risks

Individual responses to WBV vary depending on the intensity, frequency, and length of exposure. People are sensitive to vibrations within the frequency range of 0.1-100 Hz. Vibrations in automobiles might be too intense to be perceived, affecting vision and balance. ISO 2631-1 (1997) identified these consequences as health risks, comfort and motion sickness.

The health hazards associated with WBV have prompted vehicle manufacturers and businesses to focus on limiting vibration exposure and discomfort [17]. The desire to expand working capacity, quality of work, and competitiveness leads to reduced discomfort and increased productivity while lowering health hazards. Human exposure to vibration has a general effect on health. The magnitude, frequency, and duration of vibration exposure are all important factors in determining health effects. Vehicle drivers are frequently subjected to vibrations caused by external sources that are both periodic and transitory. Driving over bumps and potholes causes high amounts of vibration. Transient vibrations are more detrimental to health than periodic vibrations [18], causing physiological and psychological suffering in humans. The distress produced can range from acute to chronic health hazards [19].

WBV's physiological consequences include degradation of the human body's cardiovascular, respiratory, endocrine, metabolic, motor, sensory, and central neurological systems. Several types of physiological impacts from vibrations occur concurrently, such as increased heart rate correlated with increased frequency of breathing during moderate vibration exposure, lung ventilation, and increased oxygen use. .

A review of the epidemiological literature on vibrations reveals that occupationally linked vibrations cause lower back pain [20]. Improving seat and tyre qualities is one of the most effective ways to reduce the prevalence of back discomfort. Regular vehicle and equipment design improvement, use of low-vibration surfaces, and regular maintenance can reduce health risks [21].

1.4.2 Ride Comfort and Perception

Comfort is a comprehensive description that includes both physiological and psychological components, such as subjective feelings of well-being, and is simply described as the absence of discomfort. Comfort is determined by the magnitude of vibration and the occurrence of shocks or transients. Seating discomfort is assessed using both objective and subjective approaches. The objective techniques include physiological testing, such as seat pressure monitoring using electronic devices [22-23], whereas the subjective assessments are done in two ways: a paired comparison technique and rating scales.

1.5 Vibration Measuring Methods

According to the standard regulations, vibrational oscillations are measured in terms of accelerations. The vibration measurements will be taken at the interface between the determined vibrating platform and the human body. Gryphon in 1990 [24] developed a comprehensive model outlining the measuring system for vibrational analysis of automobile operators, which is based on measuring vibrations.

Depending on the frequency of stimulation, vibration has an impact on health, comfort, and motion sickness. Several testing methods have been established in the automobile industry to estimate the vibrational comfort of the seat. The ISO 2631 and BS 6841 rules specify a number of frequency weighting filters for calculating comfort ratings. [25-26]. It is significant to remark that, for different axes of vibrations, different frequency weightings are required; nonetheless, some frequency weightings are often chosen for more than one axis, with the objective of minimising the number of weightings for axis.

According to ISO 2631-1 1997 (1) standards [1], vibration evaluations should always include measurements of weighted root mean square (RMS) acceleration, which is a statistical measure of a constantly changing quantity. It is particularly useful for calculating mean acceleration values, which can be both positive and negative signals, but squaring the values converts all of them to positive quantities. The weighted r.m.s acceleration is expressed in m/s^2 for translational vibrations and rad/s^2 for rotational vibrations.

1.6 Motivation

Agricultural vehicles, particularly tractors, serve as vital tools for efficient farming, yet the comfort and health of their operators are often compromised due to the physical challenges posed by vibration exposure. The primary motivator for undertaking a PhD study in this area stems from the need to enhance the ride quality, performance, and overall well-being of tractor operators, whose health is affected by prolonged exposure to vibrations, often experienced under harsh working conditions such as rough terrains.

The phenomenon of vibration in vehicles, particularly within the context of agricultural machinery, presents a complex interaction between mechanical systems, human physiology, and environmental factors. Vibrations, especially whole-body vibrations (WBV) and hand-arm vibrations (HAV), have long been acknowledged as a contributing factor to discomfort, motion sickness, and even severe health conditions such as musculoskeletal disorders, neurological damage, and cardiovascular impairments in vehicle operators. Despite this, there remains a gap in understanding the specific contributions of different vibration sources in agricultural vehicles, and in developing effective methods to mitigate their negative effects on driver comfort and health.

A detailed analysis of vibration sources, including indirect excitations from road roughness and ground conditions, and direct excitations from the engine and driveline systems, is essential for optimizing vehicle design and reducing the detrimental health effects. Moreover, the challenge of isolating and quantifying the physiological and psychological responses of operators to these vibrations is critical in creating effective solutions. Understanding how the human body interacts with these vibrations across various frequencies is crucial to developing ergonomic vehicle seats and improving operational procedures that can mitigate the adverse impacts of vibration.

The research will focus on several areas of critical importance:

1. **Health and Safety Impact**: Assessing how different frequencies and magnitudes of vibration affect the physiological systems of the tractor operator, including the cardiovascular, respiratory, and musculoskeletal systems, will offer a direct path toward improving vehicle ergonomics. The design of effective vibration-reducing technologies will be explored with a focus on minimizing health risks such as back pain, fatigue, and more serious chronic conditions.
2. **Psychological and Comfort Perception**: The subjective and objective evaluation of comfort in agricultural vehicles is another critical area. By measuring vibration exposure through standardized methods (such as ISO 2631 and BS 6841), it will be possible to quantitatively assess the comfort of operators under various operational conditions, paving the way for improving seating designs, suspension systems, and vehicle ride quality. Research into the psychological impacts, such as motion sickness and fatigue, could lead to actionable insights for vehicle manufacturers to address these concerns.
3. **Technological Advancements in Vibration Measurement and Reduction**: Innovative techniques for measuring and analyzing vibration, such as the development of comprehensive models for vibrational analysis (e.g., Gryphon’s model), will be explored to refine existing standards and provide more precise data

on vibration exposure. Furthermore, new materials and technologies aimed at vibration isolation and reduction could be investigated, leading to advancements in vehicle design that prioritize operator health and comfort.

4. **Ergonomics and Vehicle Design Optimization**: By correlating vibration exposure data with operator health and performance, the research aims to influence vehicle design by identifying critical areas where improvements can be made. The development of optimized seating systems, better suspension designs, and improved vehicle chassis and tires could substantially enhance operator comfort while reducing long-term health risks.

The motivation for this research is therefore not only to understand the multifaceted interactions between vibration and human physiology but also to contribute to the design of safer, more comfortable agricultural vehicles that promote operator well-being, productivity, and sustainability in the agricultural industry. Through the application of multidisciplinary knowledge in biomechanics, engineering, and psychology, this research aims to establish comprehensive guidelines for reducing vibration-related health risks while improving the overall user experience in agricultural vehicles.

1.7 Organization of Thesis

This thesis is structured into six chapters, each systematically addressing critical aspects of the research to provide a comprehensive understanding of tractor seat vibrations and their impact on operator comfort. The organization follows a logical progression, beginning with foundational concepts and literature review, advancing through methodology and analysis, and culminating in findings, discussions, and recommendations.

Chapter 1 provides an introduction to the study, outlining its background, significance, objectives, and research questions. It describes the impact of mechanical vibrations on vehicle operators, particularly tractor drivers, emphasizing whole-body and hand-arm vibrations. Prolonged exposure to these vibrations, mainly through the seat, can lead to health issues such as lower back pain. Various factors, including road conditions, suspension systems, and seat design, influence ride comfort and vibration transmission. Vibrations are classified into harmonic, random, and transient types, with ISO 2631-1 (1997) providing measurement standards. Enhancing seat design and suspension systems can effectively reduce vibrations, improving driver comfort and minimizing health risks.

Chapter 2 presents a comprehensive review of relevant literature, highlighting existing research and identifying gaps that this study aims to address. This chapter explores the impact of mechanical vibrations on automobile drivers, focusing on whole-body vibrations (WBV), road roughness, ride comfort, and seat design. Various studies highlight the health effects of prolonged exposure, including spinal issues and fatigue, and discuss vibration control methods through suspension systems and ergonomic seats. Ride comfort assessments consider vehicle design, road conditions, and driver posture, emphasizing improvements in seating materials and suspension technologies. Recent innovations, such as novel seat cushions and dynamic suspension models, aim to reduce WBV and enhance driver comfort. The study explores various suspension control techniques, focusing on fuzzy logic controllers (FLC) and active control suspension systems for improving ride comfort. Existing research primarily addresses vehicle and seat vibrations separately, lacking comprehensive models for tractors with tillage implements. Identified gaps highlight the need for an advanced semi-active suspended seat with fuzzy control, including an eddy current damper. This study aims to investigate tractor seat vibrations under different conditions, analyze frequency spectra, validate a simulated tractor model, and develop PID and fuzzy controllers, ultimately enhancing ride comfort through vibration reduction.

Chapter 3 details the research methodology, including the study design, data collection techniques, and analytical methods. This chapter begins with an introduction to the mathematical modeling of the tractor-implement system, emphasizing its role in understanding and mitigating vibrations transmitted to the tractor seat for improved operator comfort. It then details the step-by-step development of the dynamic model, including the physical representation of the system, derivation of governing equations, and implementation using Matlab/Simulink. The tractor-implement system modeling section explores the dynamic behavior of the tractor with attached tillage implements, focusing on motion equations and vibration characteristics. Additionally, the role of tyres in vibration transmission is examined, along with the assumptions made for the mathematical model. Finally, the chapter introduces quarter- and half-vehicle models, which simplify the analysis of vertical, pitch, and roll motions, serving as foundational steps toward developing a full tractor vibration model.

Chapter 4 presents the research findings, outlining the experimental setup and validation of the simulation model for analyzing tractor seat vibrations. Field testing was conducted using a John Deere 5310 tractor with cultivator and disc harrow as tillage implements. A tri-axial accelerometer and data acquisition system were used to measure seat vibrations in different directions at varying tractor speeds. The analysis of experimental results showed that seat vibrations increased with speed, with the highest vibrations occurring in a specific direction due to forces from the tillage implements. To further analyze and control these vibrations, a full tractor Simulink model was developed, incorporating a Fuzzy-PID controller. The model used field discontinuities as inputs and measured seat accelerations based on real tractor specifications. The final section of this chapter discusses the validation of the simulation model by comparing its outputs with experimental data, confirming its accuracy in replicating seat vibrations. The findings highlight the importance of vibration analysis for improving operator comfort and suggest that the validated model can serve as a foundation for future research on tractor seat suspension systems.

Chapter 5 discusses these results in relation to the research objectives and literature review. This chapter presents the system controllers for semi-active seat suspension, detailing the role of variable damper actuators in vibration management. It begins with an overview of the PID control system, explaining its proportional, integral, and derivative components for stability and precision. The Fuzzy-PID control system is then introduced to address the nonlinearity and time-variance of seat suspension, incorporating fuzzy logic for dynamic parameter adjustment. Numerical simulations follow, analyzing seat acceleration, displacement, and velocity using MATLAB. The performance of designed controllers is evaluated through RMS and peak-to-peak acceleration values. A frequency domain analysis is conducted to assess vibration reduction across different frequency ranges. The results are validated experimentally by redesigning the tractor seat with an MR damper, replacing the hydraulic damper. Experimental findings confirm the effectiveness of the Fuzzy-PID controller in reducing seat vibrations. Comparative analysis of simulated and experimental results highlights minor variations. The chapter concludes with a summary of findings, emphasizing improved ride comfort and reduced operator fatigue.

Chapter 6 concludes the thesis by summarizing the key findings, discussing their implications, and providing recommendations for future research. This chapter presents the key contributions of the study, followed by recommendations for future work. It begins with a summary of the research outcomes, highlighting the effectiveness of PID and fuzzy controllers in improving tractor seat comfort through semi-active suspension. The chapter then discusses the significance of vibration and acceleration reduction in enhancing operator comfort and productivity. Next, it outlines the implications of the study for future tractor suspension design and optimization. Finally, a set of recommendations for future work is provided, suggesting areas such as comparative analysis, modern control strategies, and broader experimental conditions to further refine and expand the research findings.

Many researchers have conducted extensive research into the mechanical vibrations experienced by drivers of automobiles and their impacts. This chapter describes the background and comprehensive review of the literature by various researchers. Starting with basic parameters of automobile system, the suspensions, controllers and ride comfort have been discussed. Different methods of vibration controls such as suspension systems, whole body vibrations and types of seats have also been interpreted.

2.1 The Vibrations felt by the Drivers of general Automobiles and tractors

Rasmussen (1983) conducted experimental studies to establish vibration exposure limits for humans, which led to the development of ISO Standard 2631. This standard specifies instrumentation requirements for measuring human responses to whole-body vibration and outlines necessary precautions. Additionally, ISO/DIS 5349 defines exposure thresholds for hand-arm vibrations experienced by operators of vibrating tools. The study also examined vibration effects on a chip hammer using a specialized hand adapter for precise measurements. The vibrations experienced by drivers of general automobiles and tractors were also considered, highlighting the necessity of assessing their exposure levels to ensure compliance with established safety standards. [31].

Shivakumara et al. (2010) conducted an evaluation of vibration levels affecting motorcycle riders under varying road conditions. Their findings indicated that whole-body vibration (WBV) and hand-arm vibration (HAV) propagate through the entire body, leading to localized effects that disrupt normal physiological functions and impact overall health. The response of individual body parts is influenced by their respective natural frequencies, with vibration-induced health risks being directly correlated to both acceleration magnitude and exposure duration. Similarly, the vibrations experienced by drivers of general automobiles and tractors must be analyzed to assess their impact on ride comfort, fatigue, and long-term musculoskeletal health. [32].

Waleed et al. (2012) assessed the human response to WBV in three modes: pitch, roll, and vertical direction. Their result was that pitch vibration had a greater impact on human tolerance than the other two, and that increasing the frequency did not significantly affect pitch tolerance. In addition, vertical mode has a lower tolerance to sinusoidal excitation than random vibration [33].

Liu et al. (2018) categorised human responses into three levels: perception threshold, discomfort threshold, and tolerance threshold. The people stood, sat, or lay down on the vibrating platform for five to 10 minutes. He discovered that, statistically speaking, the direction of vibration application had little effect on the reaction [34].

Azmi et al. (1988) investigated the impact on crane operators' health caused by exposure lasting more than five years. They concluded that accelerations between 0.2 and 1 m/s^2 resulted in significant back problems. Intervertebral disc disease is nearly three times more common among workers who have been exposed for more than five years. If the exposure lasts longer than ten years, this factor increases by almost fivefold [35]

Fatatsuka (1998) investigated the effect of WBV on the seating arrangements of agricultural tractors. WBV in wheel tractors and combine harvesters exceeded the exposure limits; there was a loss in competence owing to fatigue after 8 hours of exposure; and the decreased-comfort limits were reduced when compared to ISO 2631-1 (1997). Some of the machines were exposed for less than one hour, as required by the same regulation. Operators were less likely to report specific injuries or other impacts, such as lower back ailments, than non-operators. The studies describe the difficulty in determining impacts caused by different working conditions such as heavy material operation, working position, and so on [36].

Mehta et al. (2002) contrasted primitive and modern tractor seats in terms of comfort level. In many farming operations, the farmer sits for the most of the time, resulting in a change in weight-bearing surfaces. Other impacts include the immobilisation of the pelvis, reduced spinal movement, and flattening of normal curves. The study proposes uniformly distributing weight to avoid pressure spots and severe tensions. He also mentioned the psychological value that individuals place on the size, material, and design of the seat because it represents the status/importance of the owner/driver.[37]

Kale et al. (2015) investigated overall design of the vehicle seat in terms of comfort and safety for drivers with a focus on whole-body vibration at frequencies ranging from 0.5 to 80Hz as per ISO (2631) vibration. They determined that continuous driving caused shoulder and lower back pain in both drivers and passengers due to faulty design and unequal pressure distribution.

According to Seidel et al. (1993) long-term exposure to whole-body vibration can most likely contribute to degenerative changes of the spine in both male and female participants, as well as disruptions of pregnancy abortions and stillbirths in females, with only a minimal influence on hearing loss [38].

Boileau et al. (1998) investigated the elements influencing the transmission of vibration in vehicles and discovered that the vibration transmitted affects ride comfort depending on the frequency, direction of the input motion, and seat characteristics for on- and off-road vehicles. It further investigated that vibrations up to 12 Hz affected all human organs, however those over 12 Hz would only have local effects [39].

Santiago et al. (2023) The ISO 2631-1:1997 standard describes the measurement methods, weightings, and equations required to identify when mechanical vibrations exceed a frequency and acceleration-dependent characteristic. Using the ISO 2631-1:1997 standard, a prototype was created to measure variables using an MPU-6050 accelerometer and appropriate processing of raw acceleration data obtained via the I2C communication protocol. An embedded system was utilised to alter acceleration data in order to get a Z-axis vibration frequency ranging from 1 to 30 Hz. The ISO standard recommends focusing on the Z-axis because of its position in the driver's seat and the potential of worsening mechanical vibrations caused by accidents [40].

Zhang et al. (2024) conducted an extensive investigation to evaluate the impact of WBV frequency on driver fatigue. Six one-hour driving simulation sessions were completed by fifteen individuals, each of whom was subjected to WBV. The Karolinska Drunkiness Scale (KSS) was used to quantify subjective sleepiness. Reaction time, which gauges attentiveness and focus, was significantly lowered in the two lowest frequency levels [41].

Various studies have examined the effects of whole-body vibration (WBV) and hand-arm vibration (HAV) on human health and performance. Research has led to the establishment of vibration exposure limits and international standards for measuring human responses to vibrations. Findings indicate that WBV and HAV impact physiological functions, musculoskeletal health, and overall comfort, particularly for motorcycle riders, automobile drivers, and tractor operators. The vibrations felt by the drivers of general automobiles and tractors can lead to discomfort, fatigue, and long-term spinal issues, making it essential to assess their exposure levels. Pitch vibrations significantly affect human tolerance, while exposure duration and acceleration magnitude play a crucial role in discomfort and fatigue.

Long-term exposure to WBV has been linked to severe back problems, spinal degeneration, and fatigue, with risks increasing over time. Seat design is a key factor in reducing discomfort, as poor weight distribution and improper support contribute to spinal stress. Vibrations below 12 Hz affect multiple organs, while those above 12 Hz have more localized effects. Recent developments have focused on measuring and analyzing Z-axis vibrations, as they are critical for evaluating driver exposure and safety. Low-frequency WBV has also been found to increase driver fatigue and reduce attentiveness, highlighting the need for effective vibration control in automobiles and tractors to improve safety and long-term health.

2.2 Experimental and Theoretical Methods to Measure and Predict the Vibrations felt by the Drivers/Operators of Tractors

Szczypiński-Sala et al. (2023) conducted an in-depth investigation into the influence of test site unevenness on ride comfort across five distinct vehicle categories, emphasizing the role of speed variations. Utilizing a high-precision vibration dosimeter (VIB-008), they captured multi-directional vibration data, while geolocation parameters, including latitude, longitude, and velocity, were concurrently recorded via a GPS-equipped smartphone. To quantitatively assess ride comfort, the researchers formulated a Comfort Index (CI), integrating speed and vehicle classification as key determinants. Their findings revealed a substantial increase in discomfort levels induced by speed bumps, even when vehicles operated at speeds significantly below typical highway limits. The study underscores the necessity of accounting for external physical disturbances in evaluating ride quality. Furthermore, it draws attention to both experimental and theoretical methodologies employed in measuring and predicting driver and operator exposure to vibrations, particularly in tractors and heavy-duty vehicles. The integration of real-world field testing with computational modeling enables a comprehensive assessment of vibrational effects on human comfort and long-term musculoskeletal health. The research highlights the critical need for advanced suspension designs and refined predictive models to mitigate adverse vibration impacts in agricultural and transport sectors. [42]

Nawayseh (2015) conducted a comprehensive study on the influence of seating posture on vibration transmission characteristics in automobile seats. The investigation involved ten male participants operating a sedan at a constant velocity of 60 km/h, adhering to six predefined seating configurations. Vibration Dose Values (VDV) were systematically recorded at both the seat pan and backrest to assess directional vibration propagation. The results demonstrated a pronounced effect of backrest inclination on VDV distribution across different axes. Specifically, an increased backrest angle led to an elevated VDV along the longitudinal (x) axis, indicating amplified forward-backward vibrations. Conversely, VDV along the lateral (y) axis exhibited a decreasing trend with a more reclined backrest, suggesting a reduction in side-to-side oscillations. Additionally, the study established that a steeper backrest resulted in a higher VDV at the backrest compared to the seat pan, indicating a shift in vibration energy transmission from the seat base to the backrest structure. These findings have significant implications for ergonomic seat design, particularly in minimizing vibration-induced discomfort and mitigating potential long-term musculoskeletal risks for drivers and operators of general automobiles and tractors [43].

Cantisani et al. (2010) study explored the relationship between Whole-Body Vibration (WBV) levels, which were measured as the weighted total acceleration, and the International Roughness Index (IRI) to understand ride comfort. Through experiments conducted on different roads and at various speeds, the research found that ride quality is directly impacted by vehicle vibrations caused by road roughness and irregularities. This shows that smoother road surfaces lead to better ride comfort for passengers [44].

Poojari et al. (2017) utilized an FFT analyzer to measure the vibration experienced by the driver and analyzed the acceleration levels. The data were compared between an original seat and a modified seat across different road profiles (rough, bumpy, urban, highway), speed conditions (10, 20 km and 30 km/h), and driver age groups (30 years, 40 years). Additionally, a survey was conducted. The International Organization for Standardization (ISO) defines whole-body vibration (ISO 2631) as vibration frequencies ranging from 0.5 to 80 Hz. The experiments took place in India using an auto rickshaw across various road profiles and conditions. For each of the three road conditions studied, a rough road segment was selected for analysis[45]

Rajratna et al. (2016) did an experimental analysis to determine the amplitude of vibrations acting on the driver and passenger while driving on various road profiles at varying speeds. The approach used is consistent with the ISO recommendations for WBV exposure at frequencies up to 100 Hz. The study revealed that driving on uneven roads for more than 90 to 120 minutes caused significant discomfort for the motorist. As the road condition changed from rough to smooth, the acceleration level reduced. Accelerations were shown to be higher on bumpy roads and are uncomfortable, whereas accelerations on smooth roads are lower and more comfortable [46]

Difei Wu (2024) introduced a method for predicting ride comfort on urban roads by utilizing the Discrete Roughness Index (DRI). As a result, the DRI is favored over the International Roughness Index (IRI) because it is better suited to detecting local features and describing pavement roughness in short road sections. Comparative analyses demonstrated that the DRI is more effective for predicting ride comfort in scenarios involving short road segments [47].

Research has extensively examined the impact of road conditions, vehicle speed, and seating posture on whole-body vibration (WBV) and ride comfort. Experimental and theoretical methods, including high-precision dosimeters, FFT analyzers, and computational modeling, are used to measure and predict the vibrations felt by the drivers/operators of tractors and heavy-duty vehicles. Uneven test site surfaces and speed variations significantly influence discomfort, with speed bumps causing noticeable disruptions even at low speeds. Seating posture plays a crucial role in vibration transmission, as backrest inclination affects vibration intensity across different directions. Road roughness, measured through indices like the International Roughness Index (IRI) and Discrete Roughness Index (DRI), directly correlates with ride quality, with smoother roads providing better comfort. These studies highlight the need for advanced suspension designs and ergonomic seating to minimize vibration exposure and prevent long-term musculoskeletal health risks.

2.3 Vibration Suppression Techniques for Off-road Vehicle Driver Seats and Control Strategies

Peter et al. (2014) conducted a comprehensive investigation into the physiological determinants contributing to discomfort experienced in automotive seating. The study incorporated a cohort of 12 participants, whose anthropometric characteristics were meticulously analyzed through advanced physiological monitoring techniques, including near-infrared spectroscopy (NIRS), electromyography (EMG), and pressure mapping sensors. A predictive model was developed to correlate subjective discomfort levels in specific anatomical regions with physiological responses and individual body measurements. The findings underscored that key anthropometric parameters, such as height and weight, exert a significant influence on biomechanical stress distribution, particularly during prolonged seated exposure. Notably, discomfort was most pronounced in the cervical (neck) and gluteal (buttocks) regions, with variations linked to individual body morphology and postural adaptations during driving. Furthermore, the study contributes to the broader discourse on Vibration Suppression Techniques for Off-road Vehicle Driver Seats and Control Strategies**,** as vibration-induced discomfort is a critical factor in off-road and heavy-duty vehicle applications. Effective control strategies, including semi-active and adaptive suspension systems, play a crucial role in mitigating vibration exposure and enhancing ride comfort. The integration of real-time physiological feedback into vibration control methodologies offers a promising avenue for optimizing seat ergonomics, reducing fatigue, and improving long-term musculoskeletal health for both on-road and off-road vehicle operators. [48]

Heidarian et al. (2019) investigated passenger automotive seats and divided their comfort into two categories: static and dynamic. The research highlighted two aspects of comfort in vehicle seating: static and dynamic. Static comfort was mainly determined by the support provided by the seat itself, but it was also affected by the occupant's posture, orientation, and their position relative to key points within the vehicle's interior. Dynamic comfort, in contrast, was linked to the level of vibrations the occupants experienced. The study examined how factors such as user perceptions, seat design, the physical characteristics of the occupants (occupant anthropometry), and the duration of time spent sitting influenced overall comfort. Five different seats, labeled A, B, C, D, and E, were evaluated based on various parameters to understand these influences [49].

Onawumi et al. (2012) investigated the effects of ergonomic factors on the safety, comfort, and performance of Nigerian taxicab drivers while driving. The study included a PEIA, a PIE survey, and a workplace analysis to assess driver ergonomics. Six car models (Nissan, Mazda, Toyota, Mitsubishi, Peugeot, and Opel) were studied for ergonomic compatibility in drivers' workplaces. The survey determined that there is no specific limit on the model, brand, and make of taxis in the country, and the vehicles have not performed well in terms of safety and comfort. [50].

Brook et al. (2009) investigated the elements that influence driving comfort in the lower leg as a result of the driver moving the brake and accelerator pedals. A mechanism for collecting and measuring ergonomic data was created. The findings demonstrate that while manipulating the accelerator pedal, some drivers exert plantarflexion near the midway of the MVC range, while others employ the centre of the dorsiflexion range, which may be the source of additional discomfort. They conclude that their integrated system is a reliable platform for objectively collecting ergonomic data. This could help a designer better comprehend the comfort element in the lower leg when moving the brake and accelerator pedals [51].

Dai et al. (2023) Genetic Algorithm was utilized to determine the model parameters for the mass, spring and damping characteristics of a five degree of freedom truck seating suspension system. Instead of relying on traditional laboratory material testing, this method used field vibration data. The system's mass-spring-damping properties were modeled to mirror those found in the human body, which are challenging to measure using conventional laboratory techniques. This novel approach provides valuable insights for designing and developing future seating systems [52].

Vibration Suppression Techniques for Off-road Vehicle Driver Seats and Control Strategies are essential for enhancing ride comfort and reducing fatigue. Research has explored both static and dynamic seating comfort, emphasizing the role of ergonomic design, vibration exposure, and physiological factors. Advanced monitoring techniques, such as near-infrared spectroscopy, electromyography, and pressure mapping, help correlate discomfort with biomechanical stress distribution. Anthropometric characteristics like height and weight influence pressure distribution, particularly in the neck and gluteal regions. Ergonomic assessments in various vehicle models highlight inconsistencies in driver comfort and safety. Studies on pedal ergonomics reveal that foot positioning affects lower leg discomfort during driving. Suspension optimization using genetic algorithms enables better vibration control by modeling mass-spring-damping properties based on real-world data. These findings contribute to the development of adaptive suspension systems and real-time feedback mechanisms to improve long-term driver well-being.

2.4 Mathematical Models of Tractors and Operators Seat

Scutter et al. (1999) proposed a simple alteration to the driver seat of a tractor. An air gel polymer-based gel cushion replaces the old seat. The results revealed that the gel cushion not only cut costs but also boosted farmer comfort by lowering exposure to vibrations. Aside from that, employing a redesigned air cushion seat reduced farmers' low back and neck ache while and after driving the tractor. The vibration and pain caused by riding a tractor were greatly decreased [53].

Hanumant et al. (2015) The study examined the various factors involved in designing a driving seat, highlighting the complexity of this system, which includes multiple components, adjustments, and safety mechanisms. It was shown that a poorly designed driver seat can negatively affect the driver's health. The study covered all relevant parameters, including human anthropometry, ergonomic considerations, seat materials, safety features, comfort, weight, and aesthetics. The author emphasized the critical importance of safety and health parameters alongside the other design considerations [54].

Attard et al. (1991) used a computerized system to continuously monitor the air pressure, and pressure time cycle characteristics of an alternating pressure air cushion (APAC). The study involved ten healthy participants to evaluate the pressure redistribution capabilities of four different APACs. Throughout the experiments, the interface pressure consistently stayed below the specified thresholds of 20, 40, and 60 mm Hg. This highlights the importance of assessing APAC effectiveness in preventing pressure ulcers and improving user comfort.[55].

Ebe et al. (2001) aimed to improve seat comfort in static positions by examining the cushion's static physical features. The study analysed four vehicle cushions with varied compositions but the same hardness using Scheffe's paired comparison approach. Correlation of comfort ratings was performed using a sample stiffness determined by the slope of the force versus deflection at a load of 49 kgf. Lower stiffness provided more comfort than higher stiffness. However, five rectangular-shaped foam samples of varying hardness but same composition revealed no linear association between seat comfort and sample stiffness [56].

Wanga et al. (2004) studied the effects of sitting postures on the mass response of 13 male and 14 female seated occupants exposed to whole-body vertical vibration. It considered variations in posture due to changes in hand position, seat height, and the angles of the seat pan and backrest. Statistical analyses were conducted with body mass. The findings revealed that increasing the seat height led to a higher peak magnitude response, likely due to the body mass being supported by the seat [57].

Zhiming et al. (2012) carried out comprehensive tests on modal analysis to identify the structural dynamics of the vehicle seat. The results demonstrate that when the backrest's modal mass increases, resonant frequencies decrease dramatically. Surprisingly, there was an increase in resonant frequencies with the driver occupying the seat as the modal stiffness increased. Furthermore, it was discovered that when occupant weight increased, the seatback lateral frequency decreased while fore-and-aft resonant frequencies increased [58].

Yuan, et al. (2023). Three seat suspension methods are proposed and tested to enhance driver comfort: steel springs (SS), roller springs (RS), and tuned mass damper (TMD) with a negative stiffness structure. Dynamic models of these suspension systems are developed, and two indices, seat root mean square displacement and acceleration (zws and aws), are used to evaluate isolation efficiency and driver ride comfort under both random and bumpy road conditions.The results demonstrate that on random road surfaces, the zws and aws with SS suspension decrease by 10.31 percent and 20.32 percent, respectively. This indicates that SS suspension provides better ride comfort compared to RS and TMD suspension systems under similar road conditions [59].

Habegger et al. (2024). addressed the issue of whole-body vibration (WBV) affecting heavy machinery operators, particularly causing lower back pain and sciatica, a novel seat cushion has been developed. This cushion is engineered to optimize a High-Static Low-Dynamic (HSLD) stiffness isolator. While WBV spans from 0.5 to 80 Hz, humans are most sensitive to vertical vibrations within the 5 to 10 Hz range.Both experimental and numerical data indicate that this innovative cushion significantly broadens the attenuation region when compared to a standard foam cushion. When implemented on a universal tractor seat, it effectively reduces vibrations above 1.1 Hz. This advancement in vibration reduction has the potential to enhance operator comfort and mitigate associated health risks [60].

Mathematical Models of Tractors and Operators Seat, along with simulation and modeling, play a crucial role in evaluating ride comfort and vibration exposure. Studies have examined various seat suspension systems, including air gel cushions, tuned mass dampers, and negative stiffness structures, to reduce whole-body vibration and improve driver well-being. Anthropometric and ergonomic assessments highlight the impact of seat height, posture, and material stiffness on vibration transmissibility and comfort. Computational models, such as finite element analysis and biodynamic simulations, provide valuable insights into optimizing seat design and vibration isolation. Experimental studies using pressure mapping, modal analysis, and mechanical impedance testing have demonstrated the effectiveness of redesigned cushions and seatback modifications in minimizing discomfort. Whole-body vibration response functions, including seat-to-head transmissibility and apparent mass, reveal that low-frequency vibrations significantly impact driver fatigue and musculoskeletal health. Advanced ergonomic assessments utilizing CAD, CAE, and digital mock-ups aid in optimizing driver workplaces for improved reachability and field of view. Robust control strategies, including PID controllers and adaptive suspension systems, enhance vibration suppression and ride stability. Autonomous vehicle research integrates high-resolution ride comfort data into motion planning algorithms for better passenger experience. These findings contribute to the development of innovative seating solutions and vibration control techniques for off-road and heavy-duty vehicles.

2.5 Ride Comfort Testing Through Simulation and Modelling

Pankoke et al. (2007) investigated the static and dynamic impacts on seating comfort using virtual optimisation of a passenger car seat. The CASIMIR human model and seat were modelled in computer software, and finite-element analysis was performed using the ABAQUS solver. Static comfort was assessed using seat pressure distribution and numerical methods. The results revealed a strong correlation with measurements made using real-time excitation signals [61].

Dahil et al. (2019) performed an experimental modal analysis utilising the impact test method on original and casting leg models linked to the seat to investigate the effect of WBV on ride comfort in both scenarios. The study found that casting legs reduced vibration on passengers more than the original legs [62].

Demic et al. (2002) categorized whole-body vibration into four response functions: seat-to-head transmissibility (STHT), driving point mechanical impedance (DPMI), apparent mass (APMS), and transfer mechanical impedance (TMI). Their findings indicated that individuals are particularly sensitive to low-frequency vertical vibrations, specifically those below 1 Hz. For fore-and-aft vibrations, sensitivity was highest for vibrations below 0.8 Hz, decreased for frequencies between 1-5 Hz, and was lowest for frequencies above 5 Hz. Additionally, the study showed that subjects were more affected by random, multi-directional vibrations compared to single-directional vibrations, with the equivalent comfort levels being 15%-20% lower for the multi-directional vibrations. This highlights the greater discomfort caused by complex vibration patterns [63].

Liang et al. (2006) investigated lumped-parameter models of humans sitting and experiencing vertical vibrations. They utilized experimental data to evaluate and validate these models, focusing on three key response functions: Seat-To-Head (STH) transmissibility, Driving Point Mechanical (DPM) impedance, and Apparent Mass (AP). Their study involved comparing the experimental results with existing lumped-parameter models to ensure their accuracy and reliability in predicting human responses to vertical vibrations. The research aimed to enhance the understanding and modeling of how seated humans respond to such vibrational forces [64].

Shekar et al. (2014) published guidelines for constructing bus and coach driver workplaces. They also investigated the impact of various technologies on driver ergonomics. Mannequins were designed using the CATIA HBR module, and virtual evaluations were carried out using the CATIA DH2 configurator. Vehicle Digital Mock Ups (DMUs) were used for virtual ergonomics testing. The writers concentrated on determining the components that influence a driver's field of view, as well as evaluating control reachability and ergonomics [65].

Power et al. (2009) designed a truck cabin to improve ergonomics and comfort for Indian drivers, with an emphasis on Indian drivers' psychological and behavioural characteristics as well as ergonomic challenges. The relevance of truck cabin interior design in terms of ergonomics, comfort, and aesthetics is emphasised for present driving conditions in India. The concept was developed using the CATIA V5R16 digital model, which featured all of the cabin interior detailing, and the design was assessed using the RULA analytical approach and human activity analysis [66].

Chimote et al. (2013) employed ergonomic principles and advanced design tools, such as CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering), to identify optimal driver seat designs. They conducted a survey among truck drivers to examine factors related to travel time and seat discomfort. The findings underscored the importance of designing a comfortable seat for truck drivers, considering ergonomic factors such as anthropometry, physiological workload, and stress. The researchers emphasized that both comfort and safety are crucial for drivers. Using CAD software, they developed a conceptual seat model and conducted various comfort level tests to assess different driving conditions, aiming to improve overall driver well-being and performance [67].

Kim et al. (2005) created a biomechanical model of the human body in a sitting position to assess head vibration transmissibility and perceived mass during vertical vibrations. An automotive seat served as a vibration isolator for both the human body and the vehicle. It was beneficial to investigate how seat design parameters influence isolation. Attempts were made to investigate how the human body responds to various styles of seating. Additionally, a single multibody biodynamic model was utilised. Backrest support was included in this model since the human body reacts differently with and without it [68]

Dorf et al.(1995) assessed the robustness of a controller by evaluating its sensitivity, stability, and ability to meet nominal specifications despite typical parameter changes. A robust controller can meet control specifications even in the presence of parameter uncertainties and modeling inaccuracies. When designing a PID controller, it is essential to select appropriate proportional, integral, and derivative gains. Typically, a controller's transfer function is defined by its static gain, poles, and zeros. Classical linear control system theory offers various tools for designing and analyzing closed-loop response controllers, including root locus, Bode, and Nyquist diagrams.Gensor et al. (2023) in their study offers a unique technique for obtaining ride comfort data to enhance the motion and route planning algorithms of autonomous vehicles. The suggested methodology contrasts several comfort derivation techniques and offers a broad framework for evaluating comfort. The high-resolution outputs can be used to feed datafusion systems with more information, promoting the effective and passenger-focused development of autonomous vehicles. Furthermore, the framework's modular design enables integration with hardware or software for loop tests that yield vehicle dynamics data. This case study shows that acceleration signal peaks crucial to comfort are really present at some test sites. Critical portions of the comfort road are determined using the three methods that have been presented: thresholding, ISO 2631, and the IRI approach. For TS1, the critical sections are found at 3.97%, 36.53%, and 32.07% of the section length for the acceleration in the x, y, and z directions, respectively [69]

2.6 Fuzzy Logic Controllers

Jianfeng et al. (2013) applied fuzzy control to semi-active suspension in a computer simulation of the full vehicle. The simulation results suggest that a fuzzy controller magneto rheological semi-active suspension system could lessen body acceleration, improve ride comfort and safety, and lessen suspension and tyre deformation [70].

Yuvapriya (2017) suggested designing a fuzzy logic controller to reduce vibration in the entire vehicle model. The PID controller, passive suspension system, and fuzzy logic controller were compared for performance. The simulation findings showed that, in comparison to PID and PSS, FLC greatly reduced the root mean square values of the body's accelerations for FCM.

Also, PSD of body acceleration with FLC is within the human sensitivity frequency range that provides better travel comfort for the passengers [71].

Guclu (2005) investigated the dynamics of an eight-DOF vehicle model with passenger seats and suspensions. Due to dry friction, the model was nonlinear. This is used to reduce vibrations in the seat. Simulations validate the Fuzzy Logic controller system's success [72].

Abdulaziz et al.(2018) developed a novel and cost effective fuzzy controllers for active seat suspension. For controller development inexpensive and available preview information was used and simulation results indicated that the controller greatly improves the riding comfort as compared to passive system.Furthermore, the fuzzy supervisor had access to specific information such as body height, steering angle, driving speed, brake pressure and longitudinal acceleration. According to these inputs sub controllers can be assigned with weighted factors. A semi-active suspension system and a passive system with step input were compared to evaluate its efficacy. There was a notable decrease in wheel displacements and overshoot of transient body responses as compared to passive suspension [73].

Holouet et al. (1996) studied a semi-active suspension system using a fuzzy logic controller. To evaluate the suggested controller, the system's performance was compared to that of a passive system and another semi-active system using the on-off skyhook technique. The simulation findings showed that vigorous suspensions outperformed quiet suspensions [74].

In scientific literature there is a multiple work on controlled suspension system. The first article on active suspensions was published in the 1950s by Federspiel-Labrosse (1954). Hedrick and Wormely (1975) conducted one of the first reviews of controlled suspensions. The other was made by Goodall and Kortüm (1983) and explored the active suspension strategy. Sharp and Crolla (1987) performed a comparitive assessment of benefits and shortcomings of different kind of suspensions. Crolla (1995) tried to outline another historical review and some design norms. The type of actuation is the first consideration when designing a fully active suspension. Pneumatic, electromagnetic, hydraulic, or a combination of the three can be used as the actuator. Martin et al. (1999) presented electromagnetically controlled hybrid suspension; Williams et al. (1996) examined the benefits of a hydro-pneumatic actuator; and Satoh et al. (1990) proposed a hydraulic actuator for active suspension that employs pressure control instead of flow control [107-122]

Heidarian et al.(2024) examines the impact of two active seat suspension controllers on an articulated truck semi-trailer's ride comfort. A linear truck model with thirteen degrees of freedom (DOF) is presented in this study. A four-DOF biodynamic model is connected with this model. The definition and use of GA-PID and fuzzy-PID controllers to the seat suspension results in increased ride comfort under various driving circumstances. The first PID controller parameters are extracted by the genetic algorithm (GA), and fuzzy logic control (FLC) is used to obtain the second PID controller parameters. A linear combination of a few ride comfort parameters was thought to be the optimisation function. Based on simulation results, GA-PID and fuzzy-PID controllers have comparable performance and can enhance rider comfort and health by reducing vibration dose and motion sickness dose value (37.42%) [75].

2.7 Active Control Suspension Systems

Goodall et al. (1981) suggested active actuators for rail applications and the semi-active suspension was introduced for the first time as an alternative to an extremely complex, expensive and energy-demanding active systems. The most attractive characteristic of this study was that the control strategy was based solely on relative movement and speed measurement. Reducing dynamic wheel force is a demanding area for researchers. Cole et al.(1994) conducted expansive theoretical and experimental research on it. Valasek et al.(1998) described groundhook control logic for reduction of dynamic wheel forces [76-78].

Margolis et al. (1991) conducted the study aimed at controlling the bounce and rolling movements of large off-road vehicles. With regard to the use of semi-active suspension, they were designed for luxury cars as well as for other kinds of vehicles [79]

Groenewald et al. (1996) developed a novel technique for improving driving performance and control by altering wheel pressure using closed-loop control. Wheel-jump resonance can be controlled by adjusting wheel pressure, which will increase the behaviour close to the wheel-hop resonance, or the so-called secondary drive. Additionally, according to Shaw (1999), it lowers fuel consumption and extends the life of the wheels [80-81]

Gialamas et al. (2013) worked that vibrations developed on driver seat in Y axis are of high frequency in tractors but when implements are used for tillage purpose the vibration in X axis were also significant. Due to vibrations in both X and Y axes, there were vibrations in Z axis also. Implements have a statistically significant effect in the Z and X axes, and implements have a statistically significant effect in the Z and Y axes This article measured and analysed vibrations for various tractor and implement combinations. Checks were also performed during tractor cultivation to reduce vibration to a minimum [82].

Baesso et al. (2017) investigated the vibration levels emitted by different capacities of agricultural tractors. The outcomes were compared to the industry norms. The test was conducted with four tractors of varying strengths and durations. The vibration data was collected experimentally from different tractors and for different time durations. Data was analysed and a controller has been suggested by the authors to reduce the vibrations [83].

Kim et al. (2018) investigate the performance of autonomous driving using simulation based on driving paths and field conditions. The simulation results revealed that the curved path had higher values in the error of tyre force, tyre kinematics, and slip than the straight path.This brief survey revealed that numerous studies are being conducted and are still ongoing in the development of highly cost effective and reliable vibration controlled systems for off-road vehicles [84]

The special problem of figuring out vehicle suspension characteristics was tackled by Tan and Bradshaw (1997) and Majjad (1997). An optimising method was used since it was necessary to find a balance between suspensions that are important for road holding and comfort. Thompson (1976) developed a quarter vehicle model's controlled suspension using optimal linear state feedback theory [85-87]

Chen et al. (2022) introduced an improved firefly algorithm (IFA) to optimize the parameters of a magnetorheological damper (MRD) model. To assess ride comfort, a semi-active seat control system with three degrees of freedom (DOF) was integrated into a quarter car model. The dynamic properties of the MRD were experimentally investigated. Using the IFA, the parameters for the MRD phenomenon model were determined, leading to the development of the forward model of the MR damper. A semi-active control strategy was then designed for the three-DOF seat suspension, including controllers for both the suspension system and the MRD. The study compared the effects of passive control, PID control, and fuzzy-PID control on vibration reduction in the semi-active seat suspension under various road conditions. Simulation results showed the comparative effectiveness of these control strategies in improving ride comfort [88].

2.8 Gaps in the Literature

On the thorough scrutiny of published work on vehicle suspension system and also on the controller on the seat vibration of a vehicle model in current scenario, the following observations have been made:

- Research work is confined to control the vibrations of seat and vehicle model separately.
- The impact of vibrations on driver seat in tractors without implements used for tillage work develop the prominent vibrations in vertical axis only but when implements are used for tillage purpose the vibration in horizontal axis are also significant.
- Non-linear methods were based on simplified models e.g. vehicle model without tillage, which is insufficient to give information about the motion of a vehicle along each axis.
- Fuzzy control techniques were used on structures, quarter and full vehicles models but without tillage which developed the significant vibrations along two axis.
- Traditional seats have vertical resonances at 4 Hz, which means that vertical vibrations at this and corresponding frequencies are amplified.
- Suspended seats installed on most tractors reduce the vertical component of vibration, but the levels remain unacceptably high and necessitate further improvement.
- No attempts have been reported on the complete model of wheeled tractor with fuzzy controlled semi-active suspended seat including eddy current damper.
- Exposure to prolonged low frequency vibrations may affect human comfort. In some cases prolonged exposition to excessive vibrations may affect health.

Hence it is necessary to undertake technical measures to minimize the effect of the vibration influence on rider or driver by designing suitable seat suspension considering the implements for tillage.

2.9 Research Objectives

Researchers have paid little attention to the development and performance evaluation of appropriate vibration control systems for Indian tractor seats in a variety of operating conditions. In order to fill this gap, following objectives have been drawn in the current study.

- To investigate the effect of tillage implements at different tractor speeds on the vibration of test tractor's seat in three longitudinal, lateral and vertical directions.

- To analyze the binary effect of the type of tillage implement and the tractor forward speed on the vibration of the tractor's seat
- To analyze the binary effect of the tractor velocity and vibration direction on the vibration of the tractor's seat.
- To analyze the frequency spectra for the seat and chassis of the test tractor while plowing at different speeds, respectively.
- To validate the simulated dynamic model of the test tractor using the power spectral densities (PSDs) of the driver seat, chassis, and implement acquired from numerical simulations by comparing compared with those from experiments, respectively.
- To design PID and Fuzzy controller for the seat suspension using appropriate system variables and evaluate the Fuzzy controller by comparing it with PID controller.
- To analyze the designed controller for ride comfort using root mean square value of seat accelerations and mode shapes at critical frequencies.

CHAPTER 3

FULL TRACTOR-IMPLEMENTS AND SEAT MODELLING

This chapter focuses on the mathematical modelling of the tractor and tillage equipment system to derive differential equations for the dynamic model. The purpose of this chapter is to establish a detailed dynamic model that aids in understanding the vibrations transmitted to the tractor seat and provides a framework for reducing these vibrations, ultimately improving operator comfort. This chapter connects with the rest of the thesis by providing the foundational equations and simulation models that will be used for further analysis, validation, and optimization of tractor vibration characteristics in subsequent chapters.

The inputs for the mathematical model are field conditions and system parameters of tractor-implement system. As the dynamic model determines the relationship between input and output values so differential equations, which include temporal derivatives, are highly useful for determining the correlation between input and output data.

All vibrating systems are time dependent because input excitations and output motion responses vary with time. Most vibrating systems are complex systems, and their output is determined by a variety of factors such as excitation forces and beginning conditions. Figure 3.1 depicts the stages involved in the mathematical modelling of the system.

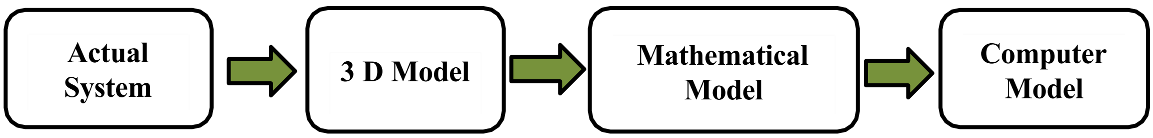


Figure 3.1 Steps Involved in Mathematical Modeling

In this study, the test tractor and implements served as the actual model. The initial stage was to investigate the actual model and determine the characteristics responsible for tractor seat vibrations, such as ground excitations. The second step was to create a three-dimensional, or physical model of the tractor-implement system. The next phase involved the derivations of governing mathematical equations for calculating mathematical formulas of the mathematical model. Finally, a computer model was developed with Matlab/Simulink tools.

The modelling component of this research consists of three major parts. The first stage is to create a full tractor and implement model. The second stage is to model the seat suspension. The semi-active suspension system controller has to be modelled in the final phase. Combining all of these models resulted in an analysis-ready overall simulation model.

3.1 Tractor Implement System's Dynamic Model

A simulation model of tractor (John Deere) with attached tillage implements has been created. The tractor's moment of inertia in relation to the central axis, as well as its mass when equipped with tools represents of the tractor body structure. A mathematical model of a tractor and its implements, also known as a tractor aggregate, is made up of numerous pieces wrapped in an envelope. All of these elements come together to make a tractor aggregate [127].

For example, when the tractor forward speed is increased, all components accelerate as a single unit, and when the brakes are applied, the tractor aggregate slows down as a single unit. To this single lumped mass, relevant mass and inertia characteristics at the centre of gravity have been added. When it comes to judging driving comfort, tyres are seen as distinct lumps of material.

The purpose of mathematical modelling of tractor aggregate (tractors and tillage equipment) is to determine the ideal parameters for lowering the amplitude of vibrations communicated to the tractor seat, hence improving riding comfort.

Figure 3.2 illustrates a dynamic tractor model with an implement. Surface roughness induces displacement excitations $q_{fz}(t)$ and $q_{rzi}(t)$in the tractor's front and rear tyres, respectively. The amplitude disparities of $q_{fz}(t)$ and $q_{rzi}(t)$ cause rotation with respect to the centre of mass. This angular displacement relative to the mass centre enabled the tractor to roll, yaw, and pitch.

Taking into consideration the time lag between $q_{fz}(t)$and $q_{rzi}(t)$the ground excitation relation between the front and rear axles of the tractor-implement system at any given instant may be expressed as

$$q_{fz}(t) = q_{rzi}(t + \tau) \tag{3.1}$$

The displacement excitations at the front and rear axles, $q_{fz}(t)$ and $q_{rzi}(t)$, and the time lag, τ can be computed using the following formula:

$$\tau = \frac{l_{bf} + l_{br}}{v} \tag{3.2}$$

When v represents the velocity of the tractor-implement system, $l_{bf}$is the distance of mass centre between the chassis and front axle, and l_{br} is the distance of mass centre between the chassis and rear axle.

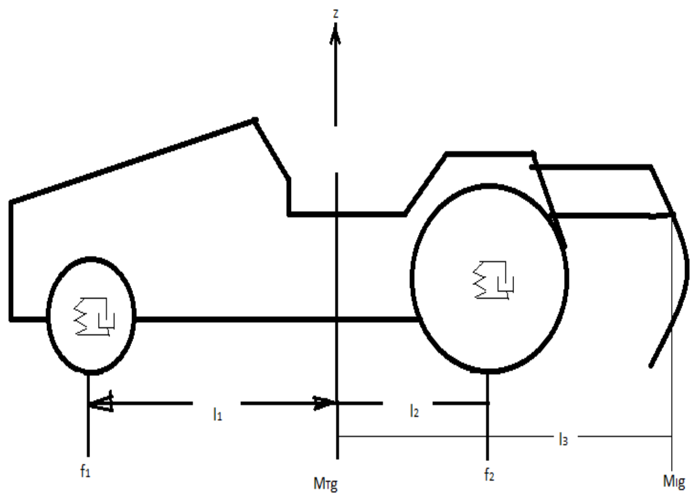


Figure 3.2 Tractor Implement Dynamic Model

The motion equations can be written as

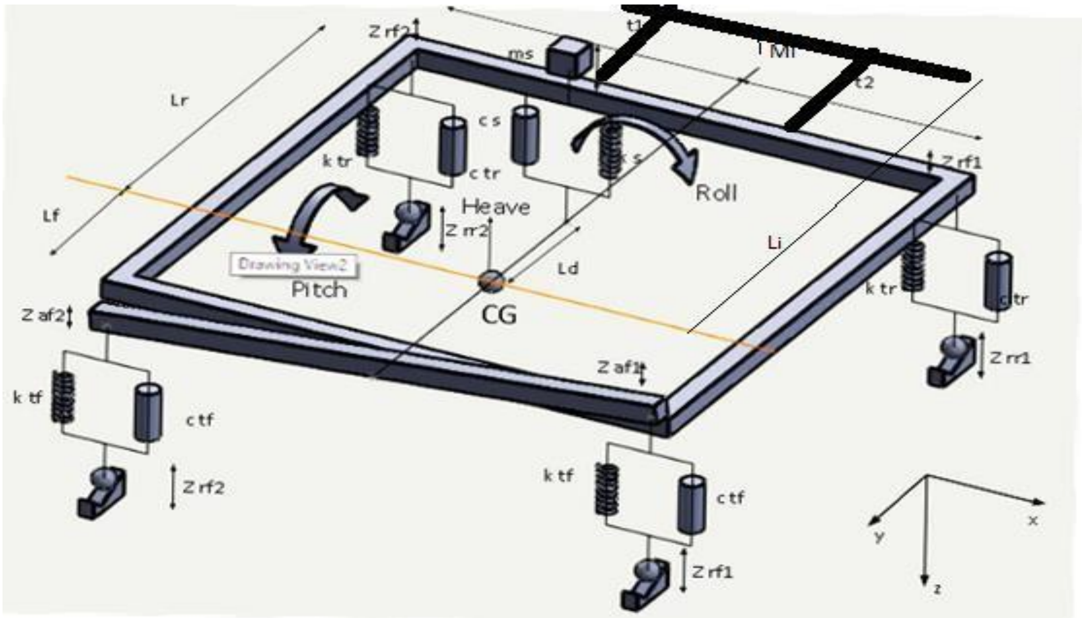
$$(M_T + M_I)\ddot{z} = f_1 + f_2 - (M_T + M_I) \tag{3.3}$$

Wheel displacement can be computed using the formula

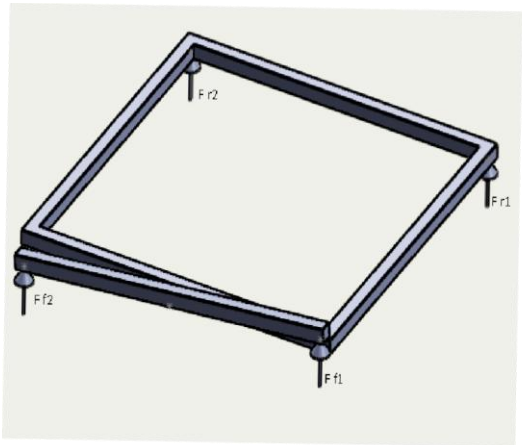
$$z_1 = z + (l_1 + l_3 \frac{M}{M_T+M_I}) \tag{3.4}$$

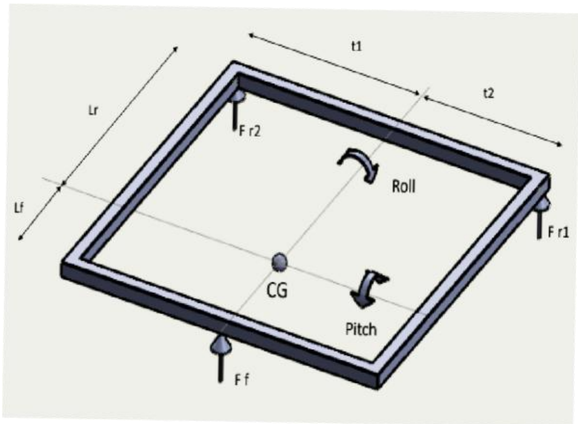
$$z_2 = z + (l_2 - l_3 \frac{M}{M_T+M_I}) \tag{3.5}$$

Tractors and other off-road vehicles are without primary suspension. The tyres work as a spring cushion due to their bending and the energy-saving properties of the air. The tractor's traditional suspension system is matched by the stiffness and damping of the tractor's tyres, as well as the driver's or operator's seat, which acts as a form of suspension for the operator.

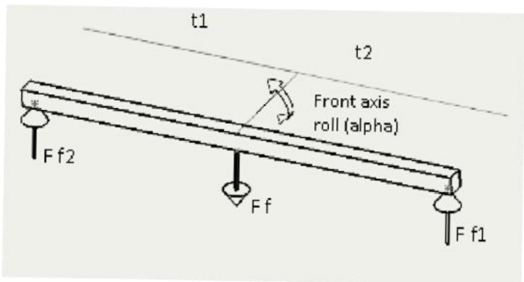


(a)





(b) **(c)**



(d)

Figure 3.3 Schematic diagrams of (a) Complete-tractor implement vibration model (b) external forces by wheels on tractor chassis (c) free body diagram of tractor and (d) free body diagram of front axle.

Table 3.1 represents the naming convention for the symbols used in figure 3.3

Table 3.1 Parameters of Complete Tractor Model

Symbol	**Description**
F_{f_1}, F_{f_2}	force transferred to the front left and right corner of the tractor chassis (N)
F_{r_1}, F_{r_2}	tractor chassis's rear left and right corners experienced force (N)
K_{tf}, K_{tr}	tractor's front and rear tyre stiffness (N/m)
z_{uf1}, z_{uf2}	the tractor chassis's front left and right corners' vertical displacement (m)
Z_{ur1}, Z_{ur2}	Tractor chassis's rear left and right corner's vertical displacement (m)
Z_{Rf1}, Z_{Rf2}	Ground's vertical undulation beneath the tractor's front left and right wheels (m)
Z_{Rr1}, Z_{Rr2}	Under the rear left and right wheels of the tractor, there is a vertical ground undulation (m).
c_{tf}, c_{tr}	Tractor wheel damping ratios, front and rear (N-m/s)
Z_{cg}	tractor's vertical linear acceleration in the Z vector (m/s^2)
m_b	Tractor body mass (kg)
I_{XXt}	Tractor mass moment of inertia about X axis (kg-m^2)
θ	pitch angular acceleration (rad/sec2) of the tractor body during motion
l_f , l_r	dimensions specifying the position of the centre of gravity from the front and rear of the chassis (m)
$\emptyset$	Roll angular acceleration of tractor body during tractor movement (rad/s^2)
I_{yyt}	Tractor body mass moment of inertia about the Y axis (kg-m^2)
t_1, t_2	The dimensions of the tractor indicate its centre of gravity with respect to the left and right sides of the chassis (m).

3.1.1 Tyres

Agricultural bumps transmit noticeable vibrations to the driver via the tyres, which serve as a buffer between the tractor and the road. This can result in cyclic loads and suspension component fatigue. Tyres, especially at high frequency inputs, operate as the initial elastic elements between the vehicle and the ground, effectively isolating it from road discontinuities.

Holst (2000) observed that it is difficult to adequately depict tyres since the stiffness and damping properties of tyres are dependent on various variables, including temperature, rotating speed, inner pressure, static load, and excitation frequency. Many academicians developed complex theories to explain all of these effects. For example, Blundell (1999) used FEM modelling as a basic model component to describe a piece of a tyre [128-131]. This allowed for the interaction of these forces to be considered alongside the impacts of longitudinal, lateral, and vertical tyre forces.

Tractor tyre stiffness and damping coefficient control the vibration that travels from the fields to the tractor chassis. Taylor et al. (2000) discovered that tractor suspension models usually employ a parallel combination of a spring and a damper rather than tractor tyres. Mechanically, the tyre can be thought of as a set of radial springs connected by dampers, with each spring making contact with the surface.

Temperature, tyre inflated pressure, and rotational speed have not been considered in this investigation because a complex tyre model was not required. In this work, the tyre model used is a linear "point contact" model with vertical forces from all force directions because the fundamental model adequately reproduced the tyre's suspension qualities. Figure 3.4 shows how the point contact tyre model can be theoretically expressed.

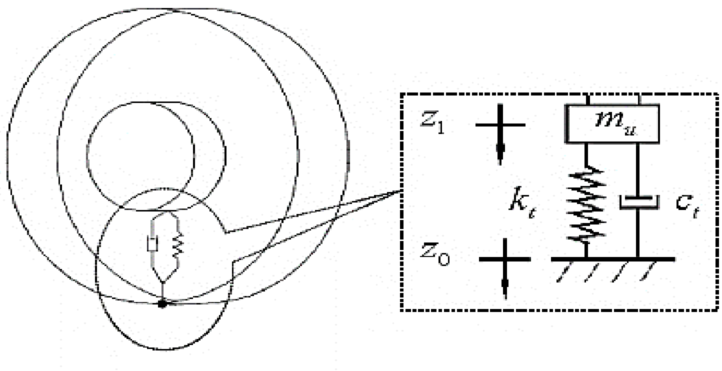


Figure 3.4 Point contact wheel model used for simulation

Because spring force varies with spring length and damper force varies with damper length over time, the vibration force transmitted from each wheel to the contact point between wheel hob and axle can be calculated as follows:

$$F_t = k(z_S - z_R) + c_t(\dot{z}_S - \dot{z}_R) \quad (3.6)$$

It is possible that the wheel's field contact will be lost instantly. Under such conditions, the calculated wheel force is negative and cannot be realised. Due to this limitation, the condition from equation 3.6 was included as

$$(z_S - z_R) < 0 \rightarrow F_t = 0 \quad (3.7)$$

3.1.2 Quarter Vehicle model

Yanget et al. (2001) provided the most basic representation of the vehicle, a quarter-vehicle model with sprung and unsprung mass, springs, and dampers [144-146]. The body mass, or sprung mass, is joined to a single tyre by a spring and damper, which is then connected to the road by another spring and damper. Unsprung mass includes the wheel, brakes, and a portion of the suspension links.

Figure 3.5 depicts the quarter-vehicle model. It is only used in circumstances when bounce motion must be addressed. In this study, Zs denotes the vertical displacement of sprung mass, Zu the vertical displacement of unsprung mass, and Zr the vertical displacement of the road. Ms and mu indicate sprung and unsprung masses, respectively.

Table 3.2 shows the fundamental parameters of the quarter vehicle model.

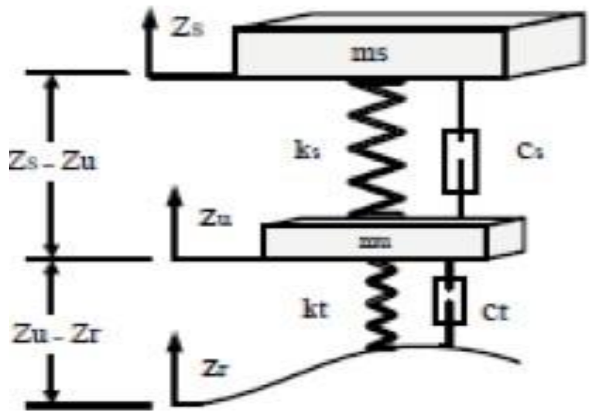


Figure 3.5 Quarter Vehicle Model

The equation of motions of the quarter vehicle model are:

1. For sprung mass ,

$$+m_s\ddot{z}_s + F_{k_s} + F_{c_s} = 0 \rightarrow \quad (3.8a)$$

$$+m_s\ddot{z}_s + k(z_s - z_u) + c_s(\dot{z}_s - \dot{z}_u) = 0 \quad (3.8b)$$

2. For unsprung mass,

$$+m_u\ddot{z}_u + F_{k_t} + F_{c_t} - F_{k_s} - F_{c_s} = 0 \rightarrow \quad (3.8a)$$

$$+m_u\ddot{z}_u + k(z_u - z_r) + c_t(\dot{z}_u - \dot{z}_r) - k_s(z_s - z_u) - c_s(\dot{z}_s - \dot{z}_u) = 0 \quad (3.8b)$$

Table 3.2 Parameters for Quarter Vehicle Model

Symbols	Description	Symbols	Description
m_u	Unsprung mass	z_r	Displacement of road input
m_s	Seat mass	z_u	Unsprung mass movement
k_s	Rigidity of Suspension	z_s	sprung mass movement
c_s	Damping of Suspension	$(Z_u - Z_r)$	Tyre deflection
k_t	Tyre rigidity	$(Z_s - Z_u)$	Suspension travel
c_t	Tyre damping		

The system can be expressed as follows in typical second order matrix form:

$$M\ddot{z} + +C\dot{z} + Kz = Az_r \quad (3.9a)$$

$$\begin{bmatrix} m_s & 0 \\ 0 & m_u \end{bmatrix}\begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_u \end{Bmatrix} + \begin{bmatrix} c_s & -c_s \\ -c_s & (c_s - c_t) \end{bmatrix}\begin{Bmatrix} \dot{z}_s \\ \dot{z}_u \end{Bmatrix} + \begin{bmatrix} k_s & -k_s \\ -k_s & (k_s - k_t) \end{bmatrix}\begin{Bmatrix} z_s \\ z_u \end{Bmatrix} = \begin{bmatrix} 0 \\ c_t \end{bmatrix}\dot{z}_r + \begin{bmatrix} 0 \\ k_t \end{bmatrix} z_r \quad (3.9b)$$

The relative displacement (Zu - Zr) between the wheel and the ground input is connected with road heeling. Suspension travel is defined by the relative vertical displacement (Zs - Zu) of the wheel and sprung mass. The suspension travel can be used to calculate the required space for the suspension elements. Driving comfort is linked to the operator's impression of the vehicle's movements. As a result, the vehicle's acceleration (sprung mass) must be minimal.

3.1.3 Half Vehicle Model

Half-vehicle models have four degrees of freedom. It usually involves either the front or back of the vehicle, or the left or right part of it. The former is commonly referred to as the roll-bounce model, and the latter as the pitch-bounce model. The half vehicle model is used to investigate the dynamic behaviour of a vehicle in response to vibrations. It is commonly used to examine a vehicle's vertical motion as well as its rolling and pitching dynamics (squatting and diving). Alexandru and Alexandru (2011) offered a dynamic study of a half-vehicle model for active suspension to improve the vehicle's dynamic behaviour in terms of stability and comfort [157].

Wang (2001) discussed research on the design and synthesis of active and passive car suspension. Figure 3.6 depicts a typical half-vehicle model with front and rear wheels examined by Campos et al., 1999. This half-vehicle model allows for the investigation of heave and pitch motions due to wheel and suspension deflections. In comparison to the whole three-dimensional vehicle model, the half-vehicle model is easier to examine while still being able to moderately estimate the system's response. In this study, the quarter and half vehicle models were created as first steps towards the full tractor model [156].

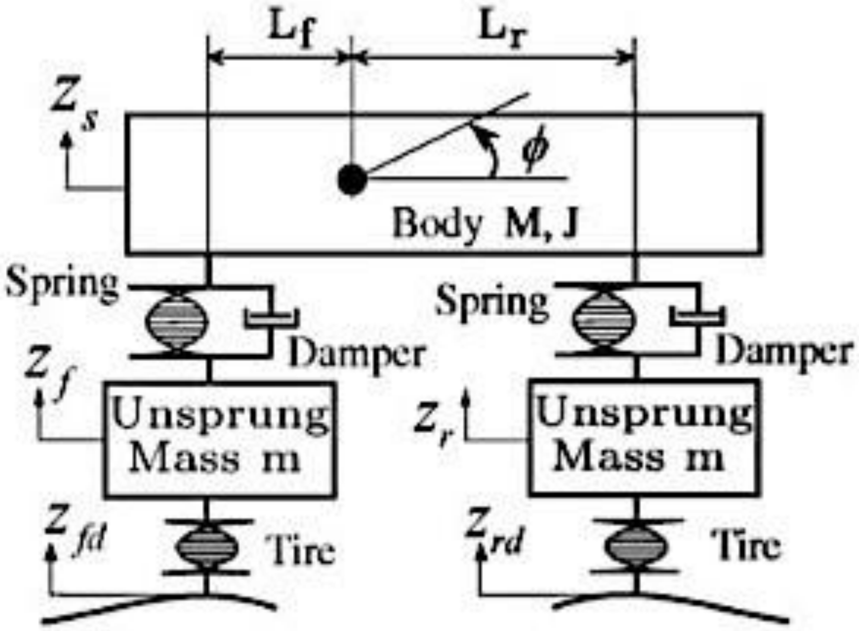


Figure 3.6 Half Vehicle Model

The equations of motion for 4 degree of freedom system or half vehicle model are:

$$M\ddot{z}_s = -k_s(z_{sf} - z_f) - c_{sf}(\dot{z}_{sf} - \dot{z}_f) - k_{sr}(z_{sr} - z_r) - c_{sr}(\dot{z}_{sr} - \dot{z}_r) \quad (3.10)$$

$$m_f\ddot{z}_f = k_s(z_{sf} - z_f) + c_{sf}(\dot{z}_{sf} - \dot{z}_f) - k_{tf}(z_{sf} - z_{fd}) \quad (3.11)$$

$$m_r\ddot{z}_r = k_s(z_{sr} - z_r) + c_{sr}(\dot{z}_{sr} - \dot{z}_r) - k_{tr}(z_{sr} - z_{rd}) \quad (3.12)$$

$$J\emptyset = L(-k_{sr}(z_{sr} - z_r) - c_{sr}(\dot{z}_{sr} - \dot{z}_r)) - L_f\,(-k_{sf}(z_{sf} - z_f) - c_{sf}(\dot{z}_{sf} - \dot{z}_f)) \quad (3.13)$$

$$\emptyset = \frac{(z_{sf} - z_{sr})}{L_f + L_r} \quad (3.13a)$$

Parameters of half vehicle model are represented in table 3.3

Table 3.3 Half Vehicle Model Parameters

Symbols	Description	Symbols	Description
M	Un-sprung mass	Z_{fd}	Front road input displacement
M	Sprung mass	z_{rd}	Rear road input displacement
k_{sf}	Front suspension stiffness	z_f	Front axle vertical displacement
k_{sr}	Rear suspension stiffness	z_r	Rear axle vertical displacement
c_{sf}	Front suspension damping	z_{sf}	Vertical displacement of front sprung mass
c_{sr}	Rear suspension damping		
k_{tf}	Front tyre stiffness	z_{sr}	Vertical displacement of rear sprung mass
k_{tr}	Rear tyre stiffness		
J	Moment of inertia about roll axis	L_f	Distance of front axle from center of gravity.
ϕ	Roll motion of vehicle body	L_r	Distance of rear axle from center of gravity.

The system in standard second order matrix form can be represented as:

$$M\ddot{z} + +C\dot{z} + Kz = Az_r \quad (3.13)$$

$$
\begin{bmatrix} M & 0 & 0 & 0 \\ 0 & m_f & 0 & 0 \\ 0 & 0 & m_r & 0 \\ 0 & 0 & 0 & J \end{bmatrix}
\begin{Bmatrix} \ddot{z}_s \\ \ddot{z}_f \\ \ddot{z}_r \\ J\ddot{\emptyset} \end{Bmatrix}
+
\begin{bmatrix} -c_{sf} & -c_{sr} & c_{sf} & c_{sr} \\ c_{sf} & 0 & c_{sf} & 0 \\ 0 & +c_{sr} & 0 & -c_{sr} \\ L_f c_{sf} & -L_r c_{sr} & -L_f c_{sf} & L_r c_{sr} \end{bmatrix}
\begin{Bmatrix} \dot{z}_{sf} \\ \dot{z}_{sr} \\ \dot{z}_f \\ \dot{z}_r \end{Bmatrix}
+
$$

$$
\begin{bmatrix} -k_{sf} & -k_{sr} & +k_{sf} & +k_{sr} \\ (k_{sf}-k_{tf}) & 0 & -k_{sf} & 0 \\ 0 & (k_{sf}-k_{tf}) & 0 & -k_{sr} \\ L_f k_{sf} & -L_r k_{sr} & -L_f k_{sf} & L_r k_{sr} \end{bmatrix}
\begin{Bmatrix} z_{sf} \\ z_{sr} \\ z_f \\ z_r \end{Bmatrix}
=
\begin{bmatrix} 0 \\ k_{tf} \\ k_{tr} \\ 0 \end{bmatrix}
\begin{Bmatrix} z_{fd} \\ z_{rd} \end{Bmatrix}
\qquad (3.13a)
$$

3.1.4 Full Tractor Model

The whole vehicle model, including the seat, is more complex, with four tyre models and a seat model to investigate heave, pitch and roll movement. The vehicle body is represented as a stiff cuboid that has three degrees of freedom. Figure 3.7 depicts the heave, pitch, and roll movements of the vehicle body.

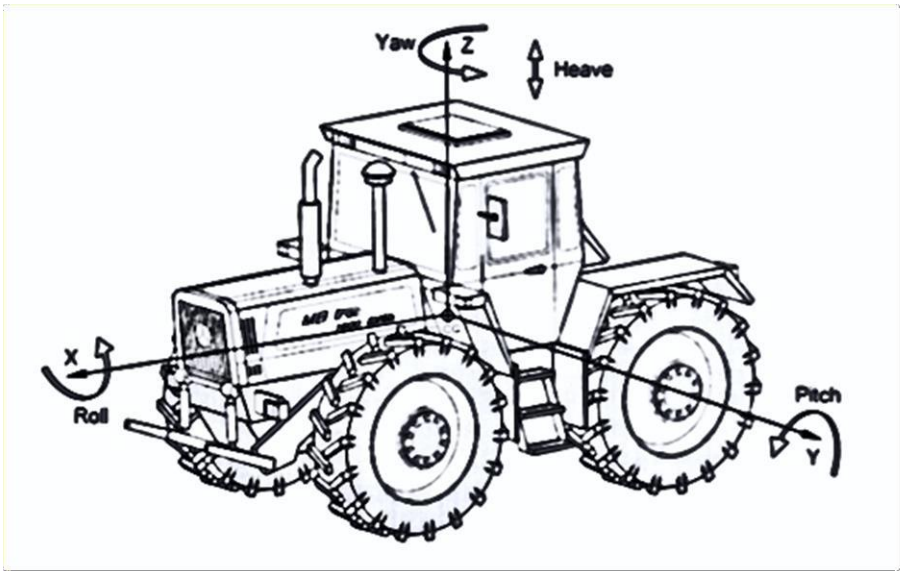


Figure 3.7 Vehicle fixed coordinate system (Sarami, 2009)

There are two types of coordinate systems: vehicle-fixed coordinate systems and space/earth fixed coordinate systems. Finding a point in space enables you to identify a vehicle's orientation and position in the earth-fixed coordinate system. The ground-attached right orthogonal axis system is used to characterise the vehicle's height and trajectory during a manoeuvre. It is normally chosen at the outset of the manoeuvre to correspond to the fixed coordinate system of the vehicle.

On board vehicle movements are specified in the vehicle's fixed coordinate system in relation to the right orthogonal system, which travels through and away from the vehicle's centre of gravity. The dynamics of the tractor pieces are depicted in figure 3.7 of this survey, which uses the next coordinate system.

According to ISO standards, the positive directions of the axes are as follows:

(i) X-axis: The forward X axis of the longitudinal plane of symmetry.

(ii) Y-axis: The lateral direction from the vehicle's right side.

(iii) The Z-axis is located above the vehicle. The angular direction of the vehicle coordinate system is determined by three rotations. Starting with the assumption that two axes are initially aligned, the following set of rotations is defined as Vehicle motions can be described using the fixed vehicle axis system as having six degrees of freedom and being associated with movements of a vehicle body, including three translation movements and three turns. Aside from that, the number of wheels equals four degrees of freedom for unsprung masses. This work contains several references to these movements and their associated themes. As a result, this section will discuss how the vehicle's body moves. Table 3.4 shows the total degrees of freedom for a four-wheeled vehicle.

Table 3.4 Vehicle Degree of Freedom

No	Vehicle Part	DOF	Motion	Axis
1	Tractor Body	Longitudinal	Translational	X-axis
2	Tractor Body	Lateral	Translational	Y-axis
3	Tractor Body	Vertical (heave)	Translational	Vertical
4	Tractor Body	Roll	Rotational	X-axis
5	Tractor Body	Pitch	Rotational	Y-axis
6	Tractor Body	Yaw	Rotational	Z-axis
7	Wheel-1	Vertical	Translational	Z-axis
8	Wheel-2	Vertical	Translational	Z-axis
9	Wheel-3	Vertical	Translational	Z-axis
10	Wheel-4	Vertical	Translational	Z-axis

A vehicle's degree of freedom is explained as follows:

(i) Lateral movement refers to moving the body left or right along the Y axis.

(ii) The z-axis represents movement up/down or in the body. In some settings, this motion is referred to as "heave" or "bounce". It is often measured near the centre of the vehicle's body mass and is thought to play a key role in suspension performance. A car body may bounce on an uneven road.

(iii) Roll is the body's rotation around the x-axis. Rolling motion excitation can be detected in the vehicle body's tilt when it turns. When a car spins around, its centrifugal force equals the centrifugal force absorbed by the vehicle's body from the road. The combined effect of these two forces leads a vehicle to tip over to one side of the curve as weight is transferred to that side, resulting in torque in the vehicle's body. The term "body roll" refers to this. The large amount of body roll poses a major threat to vehicle stability. Rolling is strongly reliant on how effectively the suspension system operates.

(iv) Pitch or Tilt: The rotation of the body around the Y-axis.

(v) Yaw: Rotation of the body along the Z-axis. A revolving vehicle exemplifies yawing motion. This form of instability can occur when curving over slippery surfaces. In this case, the rear tyres' lower traction forces are insufficient to withstand centrifugal forces, causing them to slip and the car to turn rapidly.

(vi) "Wheel hop" refers to the movement of an unsupported wheel up or down the Z axis. When analysing vehicle dynamics, movement of the wheel is equally significant as movement of the person. This action, which occurs in the Z direction, is also known as a wheel hop or jump. This shift has a direct impact on the car's stability.

3.1.5 Mathematical Passive Complete Tractor Model

In mathematical modelling, equation motion was determined for each of the five degrees of freedom. It is well understood that the force of a spring varies with its length, and that the strength of a shock absorber, or damper force, varies with its length over time (Kmajavi et al., 2007).

The vibrational forces imparted by each wheel at the point of contact between the axle and the wheel can be expressed as follows:

$$k(z_a - z_R) + c_t(\dot{z}_a - \dot{z}_R) \tag{3.14}$$

The mathematical equations for the forces transmitted to chassis are given as:

$$F_{f1} = k_t(z_{af1} - z_{Rf1}) + c_{tf}(\dot{z}_{af1} - \dot{z}_{Rf1}) \quad (3.14a)$$

$$F_{f2} = k_t(z_{af2} - z_{Rf2}) + c_{tf}(\dot{z}_{af2} - \dot{z}_{Rf2}) \quad (3.14b)$$

$$F_{r1} = k_t(z_{ar1} - z_{Rr1}) + c_{tr}(\dot{z}_{ar1} - \dot{z}_{Rr1}) \quad (3.14c)$$

$$F_{r2} = k_t(z_{ar2} - z_{Rr2}) + c_{tr}(\dot{z}_{ar2} - \dot{z}_{Rr2}) \quad (3.14d)$$

The pivot assembly of the tractor's front axle examined in the body of the tractor allows the forces exerted on the right and left wheels of the front axle to be replaced by a force exerted on the fulcrum as shown in Figure 3.3 the equilibrium equation of the front axle in the z direction is given by:

$$F_f = k_t(z_{af1} - z_{Rf1}) + c_{tf}(\dot{z}_{af1} - \dot{z}_{Rf1}) + k_{tf}(z_{af2} - z_{Rf2}) + c_{tf}(\dot{z}_{af2} - \dot{z}_{Rf2}) \quad (3.15)$$

$$F_f = F_{f1} + F_{f2} \quad (3.15\ a)$$

where $F_f$is the resultant force exerted on the pivot of the front axle of the tractor(N)

The mathematical equations of the body of tractor are the following:

(i) for the linear acceleration of the centre of gravity of the tractor in Z direction

$$\ddot{z}_{cg} = -\frac{1}{m_t}(F_f + F_{r1} + F_{r2}) \quad (3.16)$$

(ii) for angular accelerations of the tractor body about X-axis which crosses the centre of gravity of the tractor

$$\theta = \frac{1}{I_{xxt}}(F_f l_f - (F_{r1} + F_{r2})l_r) \quad (3.17)$$

(iii) for angular accelerations of the tractor body about Y axis passing through the center of gravity of the tractor is

$$\emptyset = \frac{1}{I_{yyt}}(F_{r2} t_2 - F_{r1} t_1) \quad (3.18)$$

The tractor's driver's seat base accelerates as a result of the bouncing, rolling, and pitching motion of the tractor body. As long as the distance between the tractor's centre of gravity and the seat base is known, the seat base components may be determined. (Ahmadi 2014) The tractor seat base equation of motion is as follows:

$$Z_{seat\ base} = Z_{cg} \quad (3.18a)$$

$Y_{seat\ base}$= R$\ddot{\phi}$ (3.18b)

$X_{seat\ base}$= R$\ddot{\theta}$ (3.18c)

Where $Z_{seat\ base}$, $Y_{seat\ base}$, $X_{seat\ base}$ – linear acceleration of tractor seat base in z direction, y direction and z direction (m/s^2) respectively.

According to Sarami (2009), the linear accelerations of the tractor body's force application points can be calculated using the following formula: the acceleration of the front axle pivot point and the acceleration of the rear wheel joints [188].

$$\ddot{z}_{afc} = \ddot{z}_{cg} - l_f\ddot{\theta} \quad (3.19)$$

$$\ddot{z}_{ar_1} = \ddot{z}_{cg} - l_r\ddot{\theta} + t_1\ddot{\phi} \quad (3.20)$$

$$\ddot{z}_{ar2} = \ddot{z}_{cg} - l_r\ddot{\theta} - t_1\ddot{\phi} \quad (3.21)$$

The following is an indication of the linear accelerations of the joints between the front axle and front wheels:

$$\ddot{\alpha} = \frac{1}{I_{xxa}}(F_{f1}t_1 + F_{f2}t_2) \quad (3.22)$$

Ultimately, it is possible to compute the following mathematical equations for the linear accelerations of the front wheel joint axles:

$$\ddot{z}_{af_1} = \ddot{z}_{afc} + t_1\ddot{\alpha} \quad (3.22a)$$

$$\ddot{z}_{af2} = \ddot{z}_{afc} + t_2\ddot{\alpha} \quad (3.22b)$$

This chapter presents a mathematical model for a tractor's dynamic behavior, focusing on suspension and vibration characteristics. Quarter-vehicle, half-vehicle, and full-tractor models analyze road-induced vibrations affecting chassis and driver comfort. The suspension system is modeled using springs and dampers, with forces from tyre stiffness, damping coefficients, and terrain irregularities. Governing equations, derived using second-order differential equations, describe translational and rotational dynamics in heave, pitch, and roll. The complete tractor model incorporates six degrees of freedom for the chassis and four for the wheels, capturing key vibrational modes. Adhering to ISO standards, a linear "point contact" tyre model simulates road interactions. The results provide insights into suspension performance, structural stability, and operator comfort, aiding advanced suspension design in agricultural vehicles.

CHAPTER 4

EXPERIMENTAL SETUP AND VALIDATION OF SIMULATION MODEL

In the experimental tests, there were two possibilities for conducting the test input on the test tractor: laboratory testing and actual field testing. In this investigation, the second alternative for experimental testing was deemed the best option.

The experiment was performed on John Deere 5310 tractor. The actual photographs of tractor are shown in Figure 4.1.

Figure 4.1. Actual photographs of tractor for measurement of seat accelerations

Technical specifications of the tractor used for vibration measurement are presented in the Table 4.1

Table 4.1 Technical Specifications of tractor (John Deere 5310)*

Engine	55 HP, 2400 RPM, 3 Cylinders, Turbo Charged
Air Filter	Dry type, Dual element
Clutch	Dual
Gear Box	9 Forward + 3 Reverse
Sppeds	Forward 2.7-31.8 Kmph & Reverse 3.7-24.4 Kmph
Brakes	Self adjusting, hydraulically actuated.
Steering	Power
Tyres	Front 6.5 x 20, 8 PR & Rear 16.9 x 28, 12 PR
Total Weight	2111 Kg
Wheel Base	2051 mm
Overall Length	3534 mm
Overall Width	1851 mm
Ground Clearance	434 mm
Turning Radius	3151 mm

***Source: - https://www.deere.co.in/assets/pdfs/region-1/products/tractors/55-HP-5310-4-Page-Brochure.pdf**

4.1 Tillage Implements used in Experimental Data Collection

Tillage is the mechanical manipulation of soil to manage crop residue and prepare the soil for the next crop. In other words, tillage is the digging of surface soil for physical, chemical, and biological changes to prepare a tilth for optimal seed germination and growth. The following two types of tillage implements were used in this study.

(i) *Cultivator:* A cultivator is used for cultivation in agricultural fields. It is also known as a tiller and is mounted behind the tractor using three hitch links. The cultivator's frame is secured to two staggered rows of tynes. The primary goal of having two rows and staggering the position of tynes is to create clearance between them, allowing clods and plant wastes to move through without being clogged. Tynes range from 7 to 13. Figure 4.2 shows the cultivator used in this study.

Figure 4.2. Cultivator used as a tillage implement

(ii) Disc Harrow: The concave discs that make up the disc harrow range in diameter from 45 to 55 cm. Although these discs are more tightly packed on a frame, they are smaller than disc ploughs. These discs are separated by 15 cm along the axles. Both axles feature two sets of discs. Every disc moves simultaneously with the axles. The discs penetrate the earth, efficiently breaking up the clods. Figure 4.3 shows the disc harrow used in this study.

Figure 4.3 Disc harrow

4.1.1 Measurement Procedure

1. **Purpose:** The experiment aimed to analyze seat vibrations by varying tractor forward speed and type of tillage implement.
2. **System Parameter:** The root mean square (RMS) acceleration at the tractor seat was considered as the primary performance indicator.
3. **Input Variables:**
    - Forward speed of tractor (2.30 km/h, 4.20 km/h, and 6.50 km/h)
    - Type of tillage implement (Cultivator, Disc Harrow)
4. **Measured Variables:**
    - Acceleration in X, Y, and Z directions (m/s^2)
    - RMS acceleration at seat base (m/s^2)

4.1.2 Data Processing and Possible Errors

The acquired acceleration signals were processed using a 10 Hz low-pass filter to remove high-frequency noise. The data was then transferred to a desktop computer for further analysis using MATLAB R2019a. Any potential sources of error include:

- Sensor misalignment affecting directional acceleration components.
- Loss of data resolution due to digital filtering.
- Environmental variations influencing measurement repeatability.

4.2 Experimental Setup

Tractors while on roads are generally subjected to sine wave inputs but are subjected to Step inputs while working in the fields, hence input parameter to tractor is taken as step input during analysis of vibrations at tractor seat as shown in figure 4.4

Figure 4.4 Actual test field

4.2.1 Components of Experimental Setup

The experimental setup is known as Vibration Data Acquisition System and consisting of a tri-axial accelerometer and data acquisition unit.

Tri-axial Accelerometer: The acceleration sensor used in the experiment was a piezoelectric accelerometer with a frequency range of 1 to 80 Hz and a vibration level of 0.05 m/s^2 as shown in figure 4.5. It is capable of monitoring vibrations at 5 m/s^2 root mean square with a crest factor of up to three without distortion and an accuracy of 0.05 m/s^2

Fig 4.5 Piezoelectric accelerometer

The accelerometer was installed at the base of the tractor seat as shown in figure 4.6 to measure the vibrations in three perpendicular directions.

Figure 4.6 Accelerometer mounted under seat of test tractor

Data Acquisition Unit: The acceleration sensor was connected to its own "Data Acquisition unit," abbreviated DA unit. The sampling rate of a DA unit is 800 units per second. The DA unit's function was to collect data from the acceleration sensor and record it to an SD card memory in excel format, which could then be downloaded to the desktop computer for processing. Figure 4.7 illustrates the schematic architecture of the data acquisition equipment employed in this experiment.

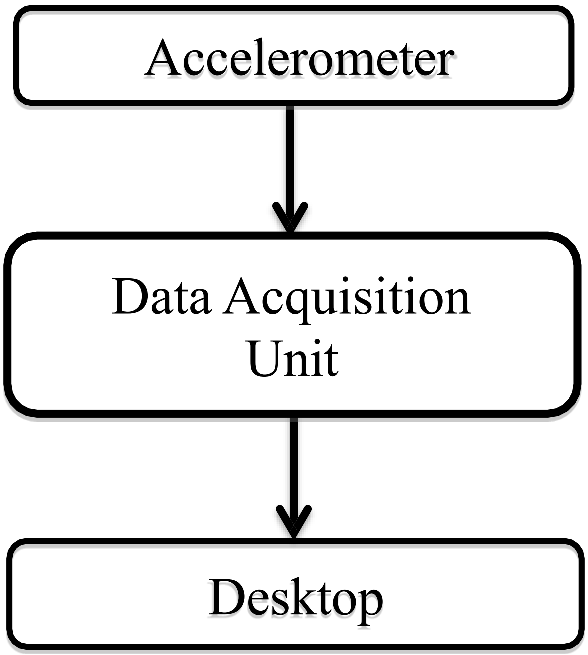


Figure 4.7 Schematic Diagram for Vibration Measurements

4.2.2 Functions of Data Acquisition System

Two main functions of data acquisition system are measurement and data logging. The sensors were used to measure output parameters of the tests and the function of data logger is to save the signals of these sensors as time history data. The obtained accelerations were stored in the memory card of data acquisition unit in the form of three excel files configuration. In order to derive the test results, these X, Y and Z axes acceleration time histories can subsequently be transferred to the computer for advance analysis. The front side of the DA unit has an LCD display and a keypad for input. Four status indicators display the battery's status. Figure 4.8 (a) shows a DA unit utilised in this investigation. One side of the DA houses an SD card slot, a USB port, an RJ11 port, a power on/off switch, and a 9v DC input. The other side of the DA unit is for attaching sensors. Because the sensor is a tri-axial acceleration sensor, it has three BNC connectors, one for each axis. Figure 4.8 (b) depicts all three axes.

(a)

(b)

Figure 4.8 (a) Data acquisition system used for test (b) X, Y & Z axis of DA unit

Figure 4.9 depicts a block schematic of the data acquisition system components. The sensors monitor the acceleration of vibrations. Sensor signals have thus been primarily converted to the necessary signals, as the signals from the sensors must be compatible with the interface card's inputs. This was accomplished by utilising a signal conditioner.

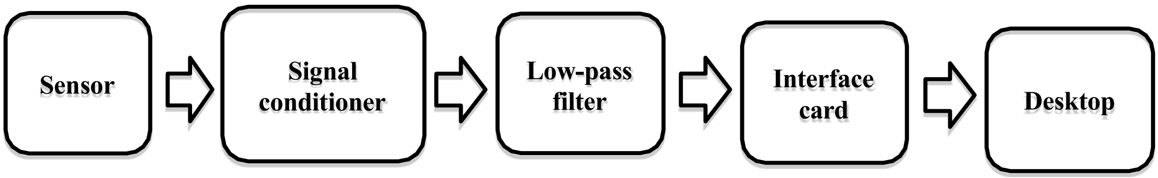


Figure 4.9 Block Diagram for Elements of Data Acquisition System

Three parts make up the signal conditioner: signal amplification, sensor isolation, and sensor excitation. The signals were routed to the card after passing through a 10 Hz low-pass filter to separate the sensor data from high-frequency and noise signals unrelated to the suspension process. Subsequently, the sensory impulses were transformed into digital signals by the ADC and stored as time history data. The recorded data was transferred to the computer via a data logger in order to do the necessary analysis.

4.3. Procedure for Measuring Seat Accelerations.

To quantify vibrations a tri-axial piezoelectric accelerometer was installed at the base of the tractor seat. In the actual test environment in the fields, vibrations caused by a tractor travelling at 2.30 km/h, 4.20 km/h, and 6.50 km/h were measured in the X, Y, and Z directions (Appendix A). The field contains steps that are 0.1 metres high, which is the input for vibrations. To test transmissibility, vibration at the seat base was monitored. Figure 4.9 depicts the procedure of recording the seat vibrations.

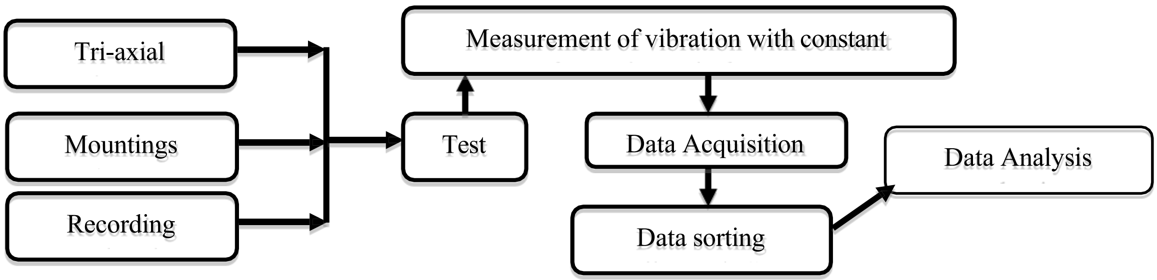


Figure 4.10 Procedure for Recording the Vibrations

The vibrations were monitored on a typical Indian farm at a certain speed range, and the data were collected while keeping the field conditions as consistent as feasible.

Acceleration levels were monitored concurrently on the axles and the base of the tractor seat in three perpendicular directions for each pass: X-longitudinal (pitching), Y-transversal/lateral (rolling), and Z-vertical. The data was processed with the Matlab R2019a software package (version 7.10, The MathWorks, India).

4.4 Analysis of Data

After recording the data, next step was to analyse the data for different inputs like forward speed of tractor and type of tillage implement. The data was analysed to get the following investigations.

4.4.1 Effect of tillage implements at different tractor speeds.

Vibrations were measured on the seat of the test tractor for two types of tillage equipment i.e. Chisel Plough and Disc Harrow. At a constant speed of 4.20 km/h, the vibration for a chisel plough is 1.41361 m/s^2, and for a disc plough, it is 2.865342 m/s^2. These results are displayed in figures 4.11(a) and (b), respectively. According to the diagrams, under comparable operating conditions, the vibration accelerations for a disc harrow are higher than those for a chisel plough.

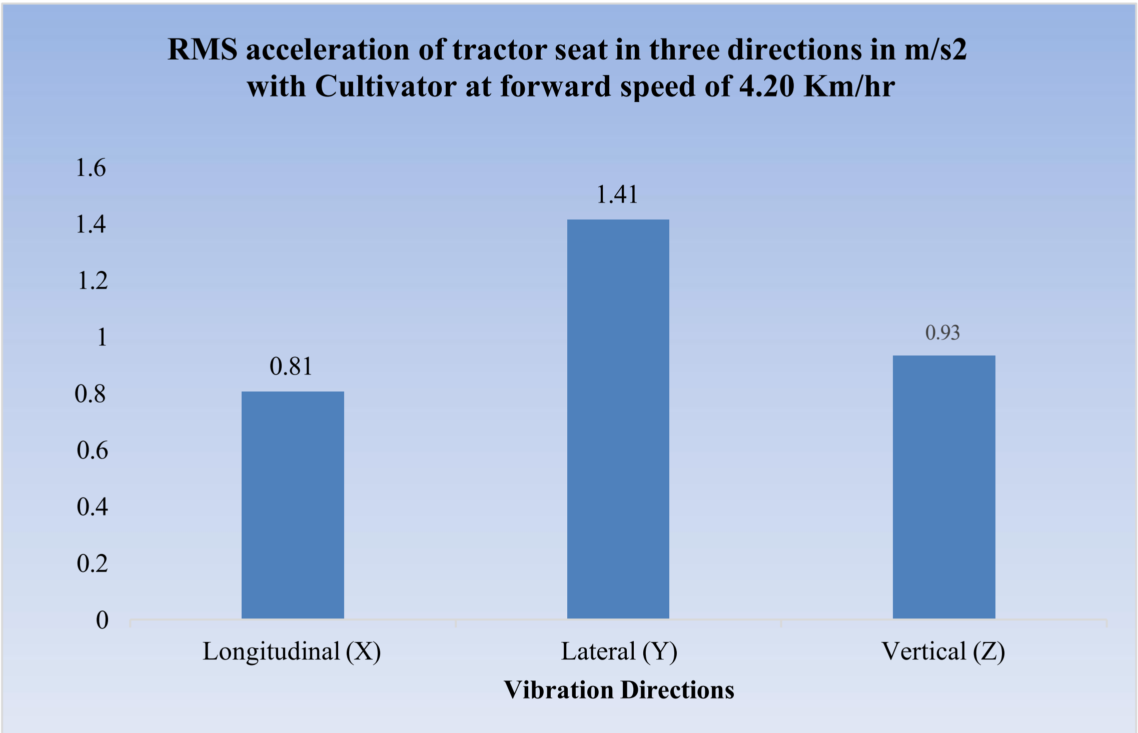


Figure 4.11(a) RMS Acceleration for Cultivator at Tractor Seat

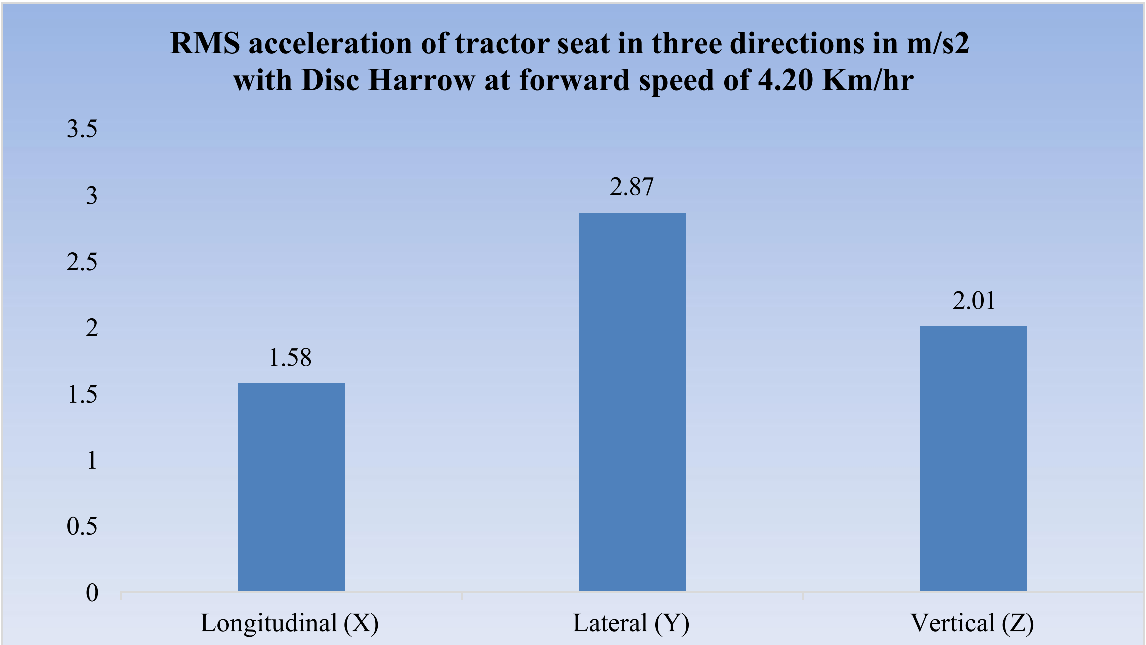


Figure 4.11(b) Root Mean Square Acceleration for Disc Harrow at Tractor Seat

4.4.2 Binary Effects of Various Tillage Implements and Tractor Forward Speed

The vibration data was collected while the test tractor was operating in the field at three different speeds: 2.30 km/h, 4.20 km/h, and 6.50 km/h. Chisel plough and disc harrow were the tillage instruments employed. Figure 4.12 shows how vibrations on the tractor seat for both the disc harrow and chisel plough equipment increase with the tractor's forward speed.

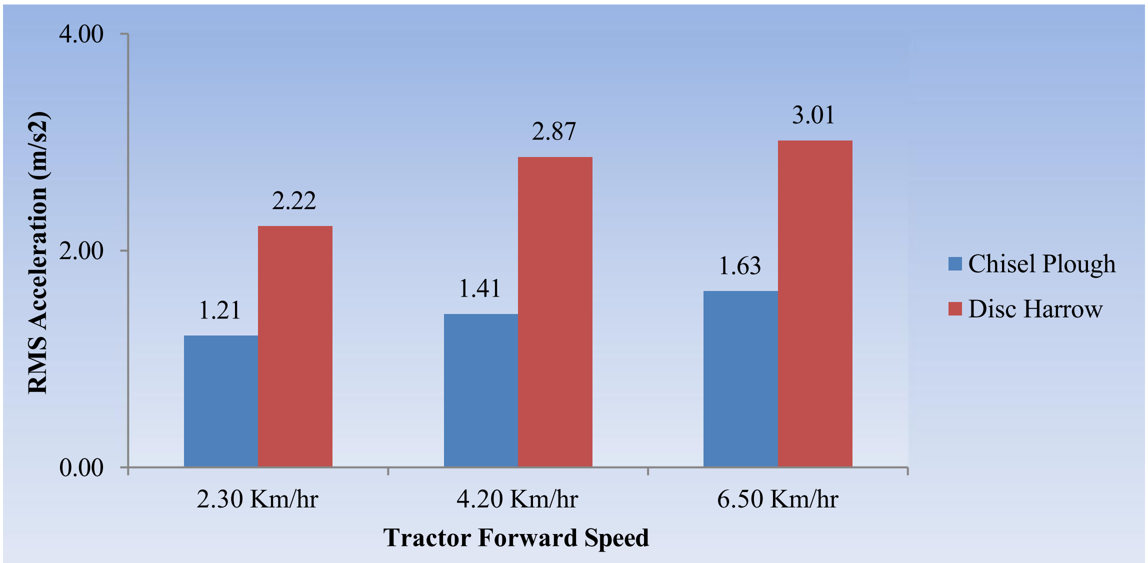


Fig.4.12 Effect on Tractor's Seat with Type of Tillage and Forward Speed

4.4.3 Binary Effects of Tractor Speed and Vibration Direction on Tractor's Seat

The vibration levels were measured in root mean square acceleration values in horizontal (x), transverse (y) and vertical (z) directions. The measured acceleration values in horizontal (x), transverse (y) and vertical (z) directions for chisel plough has been represented by bar graph in figure 4.13 (a) at different forward speeds of tractor and figure 4.13 (b) shows corresponding values for disc harrow as tillage implement. It can be observed from bar diagram that the tractor seat vibrates more in the transverse (y) direction as compared to other two directions.

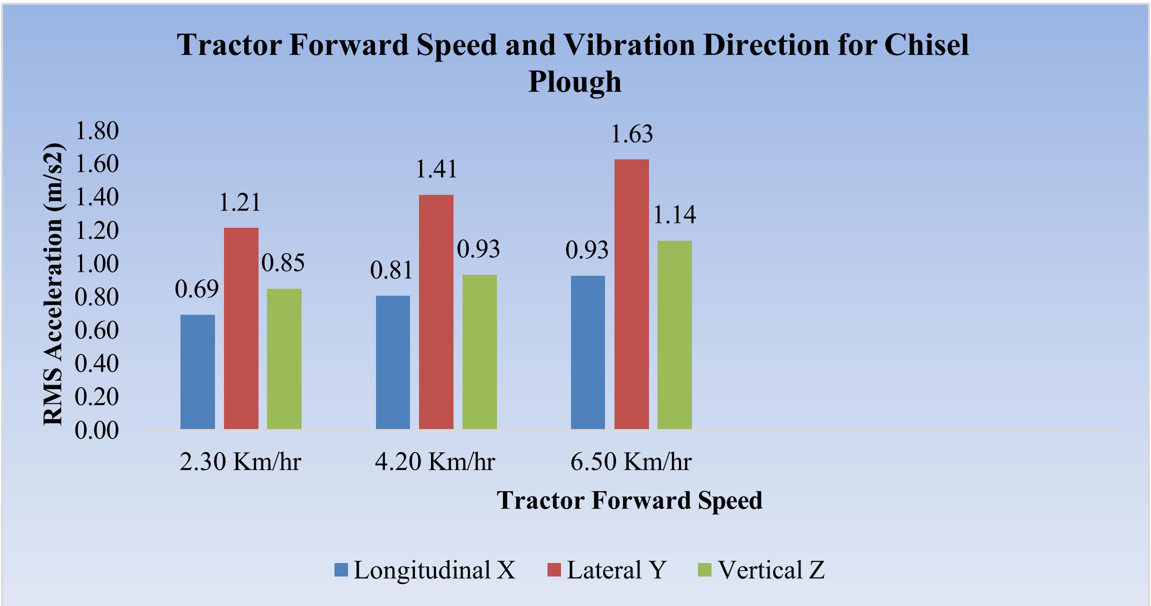


Fig 4.13 (a) Vibration Direction Values in Tractor Seat using Cultivator

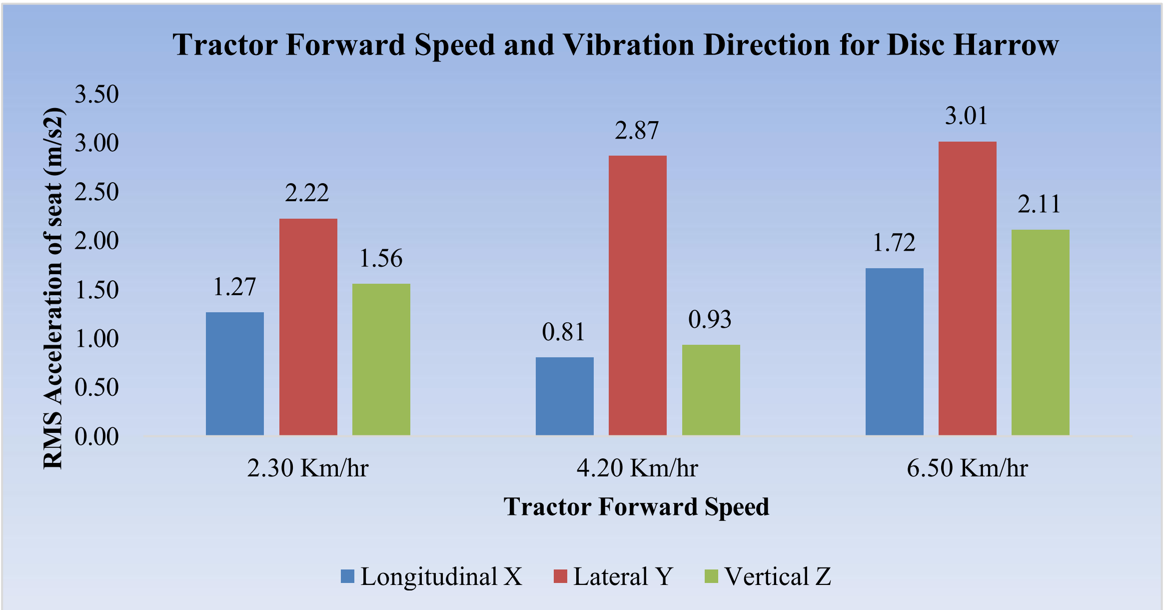


Fig 4.13 (b) Vibration Direction Values in Tractor Seat using Disc Harrow

The experimental data shows that vibrations increase with increase in tractor forward speed. It can also be observed that vibrations are highest in Y direction as compared to X and Z direction. This is due to drift force of tillage implements on the tractor. If the tractor is used without tillage implements, vibrations are highest in vertical (Z) direction.

4.5 Full Tractor Simulink Model

To model tractor seat vibrations control during tillage using a Fuzzy-PID controller in Simulink, the following steps are involved:

1. ***Model the Tractor and Tillage System:***
    - Define the tractor dynamics, including mass, inertia, and interaction with the ground.
    - Model the tillage system, including the implement (e.g., cultivator) and its interaction with the soil.
2. ***Model the Tractor Seat and Vibration Measurement:***
    - Define the seat dynamics, including mass, damping, and stiffness properties.
    - Incorporate sensors to measure seat vibrations.
3. ***Design the Fuzzy-PID Controller:***
    - Define the Fuzzy Logic and PID controller structures.
    - Determine the input and output variables for the Fuzzy Logic controller.
    - Tune the Fuzzy Logic membership functions and rules.
    - Tune the PID gains.
4. ***Implement the Control System:***
    - Combine the tractor, tillage system, seat dynamics, and controller in a Simulink model.
    - Connect the controller output to the tractor seat actuators.
5. ***Simulation and Analysis:***
    - Define simulation scenarios (e.g., varying soil conditions, tractor speed).
    - Run simulations to observe the tractor's behaviour and the effectiveness of the Fuzzy-PID controller in reducing seat vibrations.

- Analyze simulation results to assess controller performance.

The schematic diagram for experimental procedure to measure vibrations at seat base is represented in figure 4.14.

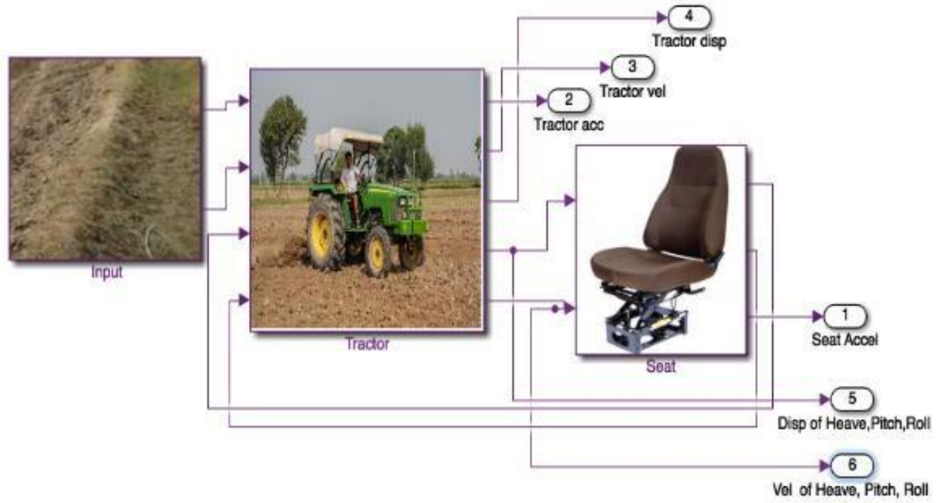


Figure 4.14 Schematic diagram for vibration measurements

Figure 4.15 depicts a MATLAB-Simulink model of full tractor with tillage implements.

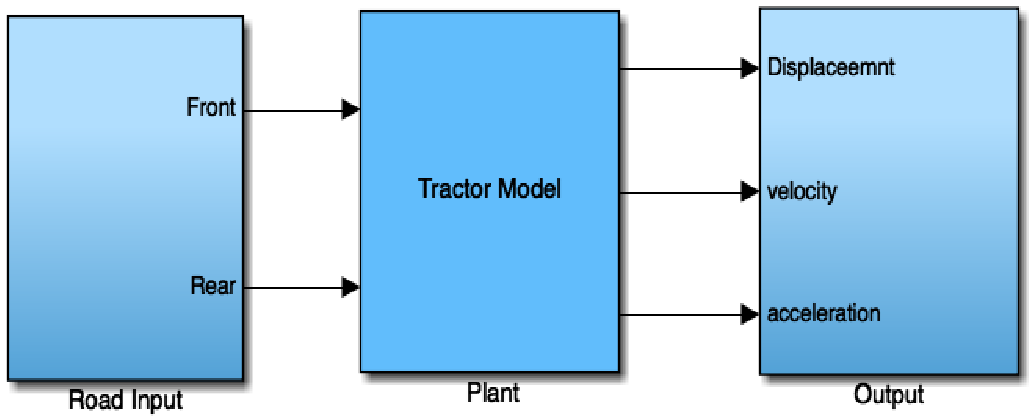


Figure 4.15 Full tractor Simulink Model

The parameters used for creating the full tractor-implements vibration model under the considerations is mentioned in Table 4.2. The inputs for the simulation were farm discontinuities in the form of vertical displacements, while the outputs were the accelerations, velocities, and displacements of the tractor seat base along the X, Y, and Z axes. The output signals were delivered to MATLAB's workspace and preserved. This data was then utilised to plot the output responses of the passive vibration tractor model.

Table 4.2 Parameters of full tractor vibration model

Notations	Description	Values	Units
M	Mass of Tractor	2110	Kg
Mc	Mass of Tillage Implement	100	Kg
a	Centre of gravity from front portion	0.6	M
b	Centre of gravity from rear portion	0.4	M
c	Tillage CG from centre of gravity of tractor	0.6	M
M_f	Mass of front wheel	40	Kg
Mr	Mass of rear wheel	70	Kg
Kbf	Stiffness of front wheel	17000	N/m
Kbr	Stiffness of rear wheel	20000	N/m
Cbf	Damping of front wheel	980	N-m/s
Cbr	Damping of rear wheel	1200	N-m/s

Figure 4.16 shows a computer model of the physical whole tractor with seat model developed using the MATLAB-Simulink programme. This model is made up of three sub models: tyre, tractor and seat. Because there is a direct relationship between all three components, their models are coupled. The model's input is excitation caused by field anomalies as seen through the tyre model. These variables serve as input for the controller.

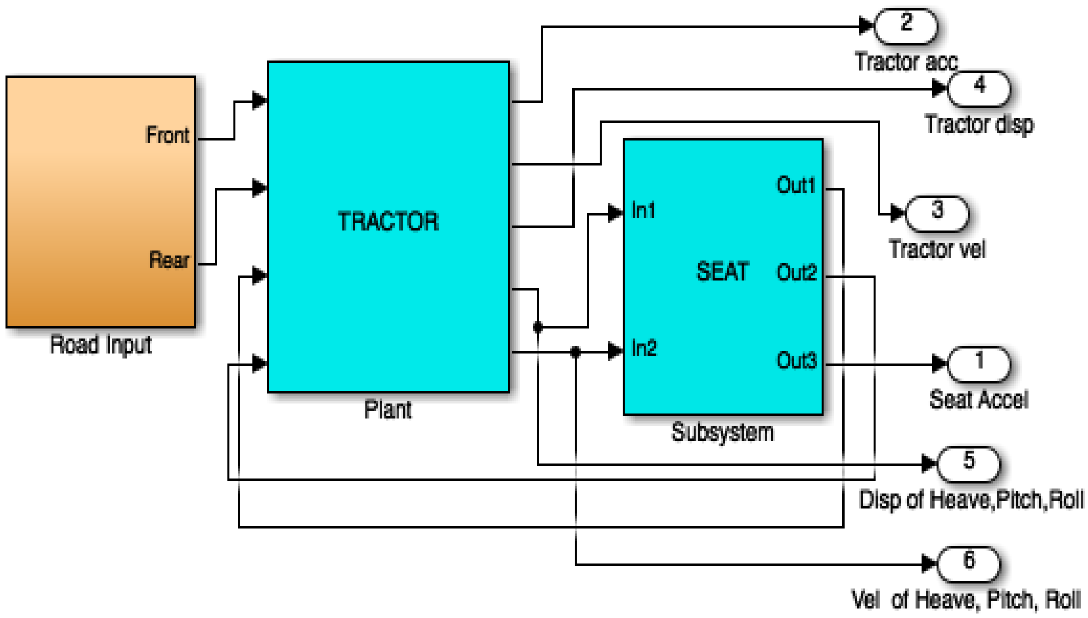


Figure 4.16 Tractor and Seat Simulink Model

Figure 4.17 (a) represents the Simulink Model of tractor and implements and for outputs of model as vibrations of tractor seat have been shown in Figure 4.17 (b).

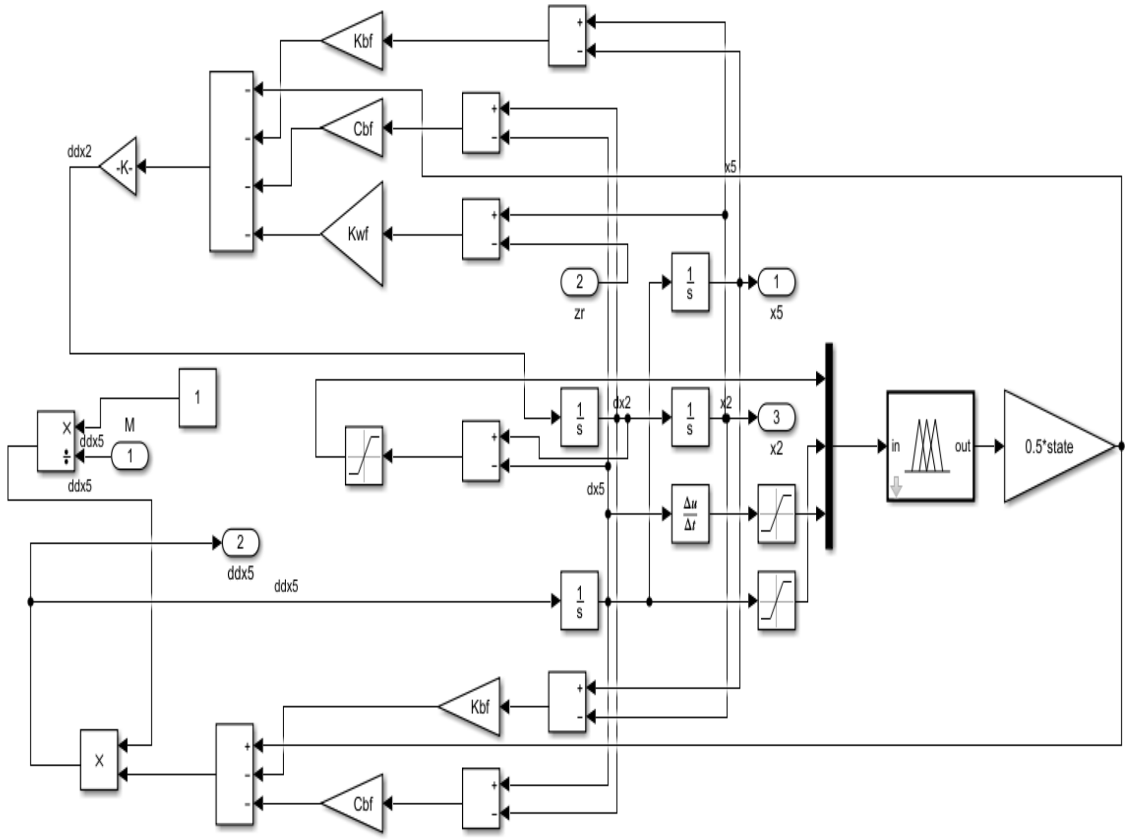


Figure 4.17 (a) Tractor and Implements Simulink Model

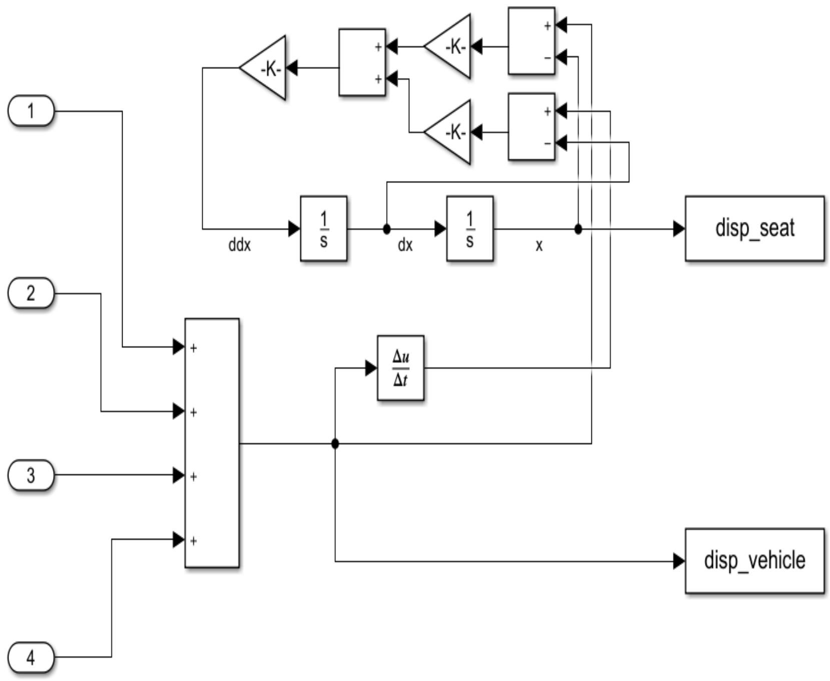


Figure 4.17 (b) Simulink Model for output values at tractor seat

4.5.1 Simulation Values of Model

The MATLAB and Simulink programme has been used to simulate the full tractor vibration model with conventional driver seat and the open loop responses of the tractor vibration system, when combined step inputs applied as field irregularities, are investigated figure 4.18 illustrate the time output responses of full tractor vibration model for all four wheels.

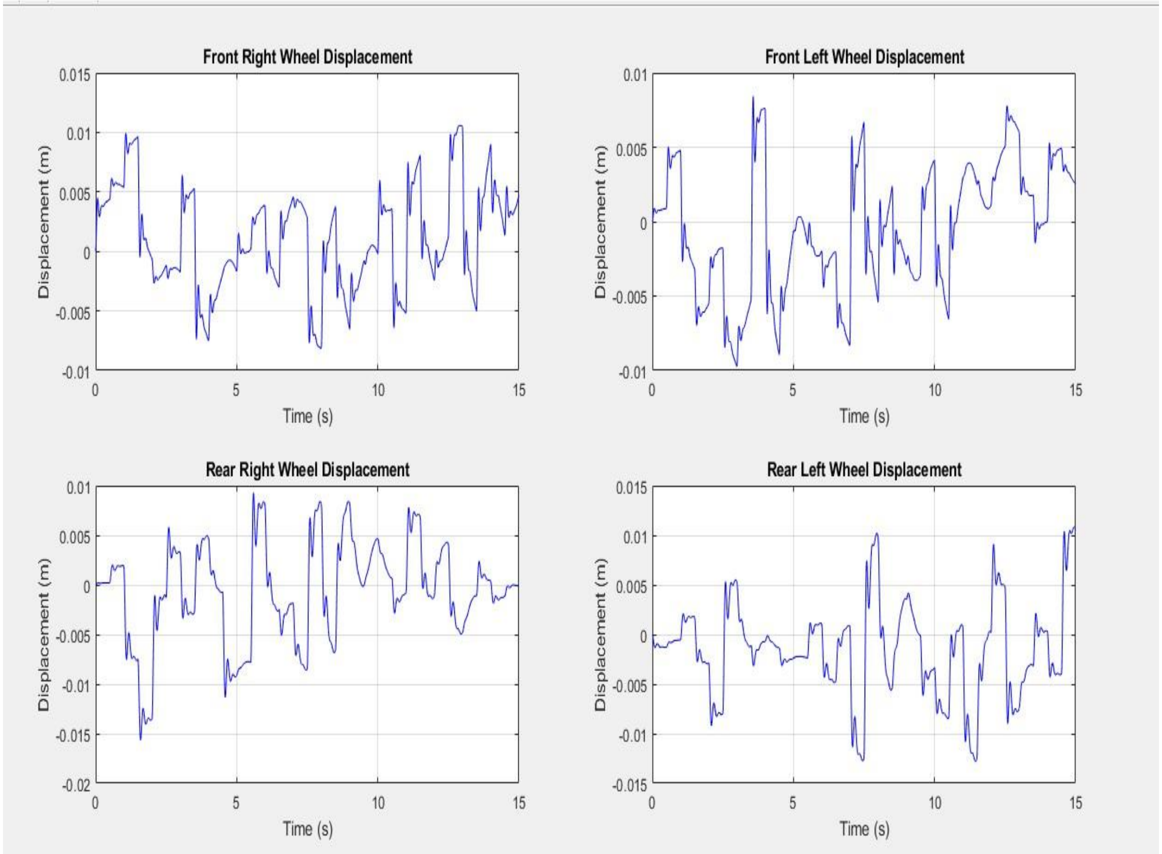


Figure 4.18 Response of Full Tractor Vibration Model for all Four Wheels

4.6 Validation of Simulation Model

Figure 4.19 depicts the model validation method. All simulation findings were compared with the relevant experimental data. Following the verification of the established model, the simulation results can be utilised to design and analyse the new semi-active seating suspension system. Furthermore, the generated model can be applied to future study in the field of farm tractor suspension systems.

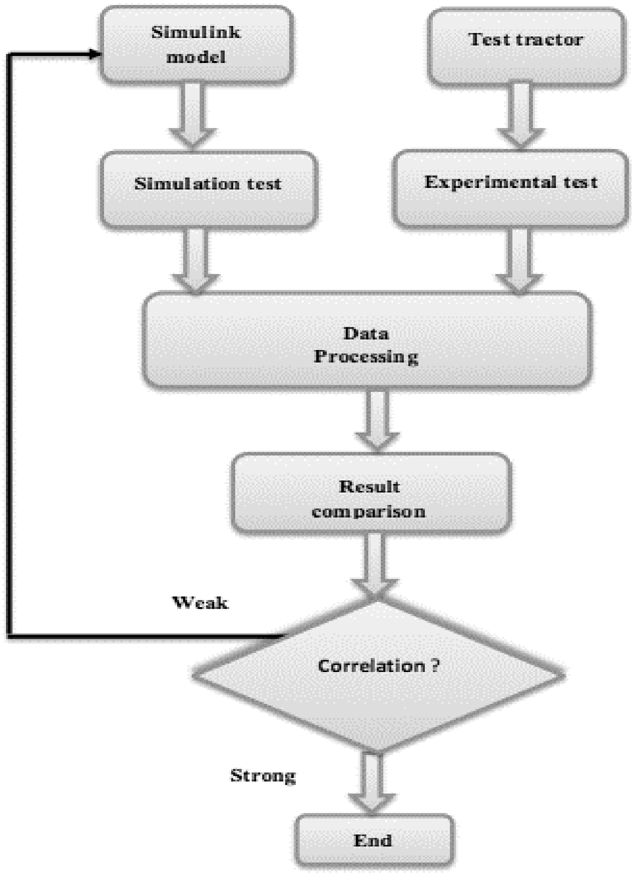


Figure 4.19 Model validation procedure

To verify the simulated model, its output was compared to the results of an experiment. Table 4.3 shows the output values of the simulation and experimental model.

Table 4.3 Simulation vs Experimental RMS values

Acceleration	Simulated Values (RMS)	Experimental Values (RMS)	Error (%)
Longitudinal Direction	0.82445124	0.80576055	2.3
Lateral Direction	1.4624207	1.413615	3.3
Vertical Direction	0.95187512	0.9329859	1.9

The inputs resulted in RMS errors of 2.3%, 3.3%, and 1.9% in the X, Y, and Z directions. As a result, the updated model demonstrated its ability to accurately replicate the acceleration of the seat base caused by a tractor traversing random inputs that replicate steps. To assess the produced vibration model, the model created in this study was compared to the RMS value of acceleration and simulation error evaluation used by other researchers Adams (2002) and Sarami (2009) [188]. The model showed acceptable results, with simulation errors of 2.3%, 3.3%, and 1.9%. The results show that the computer model correctly reproduced the vibrations caused by the field irregularity conveyed to the tractor seat. As a result, this model can be used to simulate the testing required for building a tractor seat suspension controller.

CHAPTER 5

PID AND FUZZY-PID CONTROLLERS FOR TRACTOR SEAT

Conventional control strategies for semi-active seat suspension systems, such as Proportional-Integral-Derivative (PID) controllers, are widely utilized due to their simplicity, robustness, and effectiveness in regulating dynamic systems. These controllers offer a straightforward approach to stabilizing seat suspensions by adjusting the control signal based on system deviations. However, their main limitation lies in handling nonlinear and time-varying systems, particularly those influenced by unpredictable road conditions. The fixed parameter nature of PID controllers prevents them from dynamically adapting to changing system dynamics, leading to suboptimal performance in vibration attenuation and ride comfort.

To overcome these limitations, advanced intelligent control methodologies, such as Fuzzy Logic-based PID (Fuzzy-PID) controllers, have been proposed. The Fuzzy-PID controller integrates fuzzy logic with traditional PID control, enabling real-time adaptive tuning of control parameters. This adaptive mechanism enhances the system's ability to respond to varying road excitations, thereby improving vibration damping and ride comfort in semi-active seat suspension systems.

The proposed methodology involves the development of a hybrid Fuzzy-PID control strategy that dynamically adjusts the proportional, integral, and derivative gains based on fuzzy logic rules. Unlike conventional PID controllers, which rely on fixed gain values, the Fuzzy-PID controller continuously modifies these parameters by evaluating real-time inputs such as seat acceleration, road disturbance, and suspension displacement. This adaptability ensures an optimized control response, mitigating the adverse effects of varying road profiles.

Mathematically, the semi-active seat suspension system is modeled as a two-degree-of-freedom (DOF) system comprising seat and suspension dynamics. The governing equations, derived in the previous chapter, define the relationships between seat displacement, suspension deflection, and external disturbances. The control law for the PID controller is given by:

where , , and are the proportional, integral, and derivative gains, respectively, and represents the system error. In contrast, the Fuzzy-PID controller employs a fuzzy inference system to modify these gains dynamically. The fuzzy system takes input variables such as error and its rate of change, processes them using predefined fuzzy rules, and outputs updated PID gains.

Simulation results demonstrate that the proposed Fuzzy-PID controller outperforms conventional PID control by effectively reducing seat acceleration and suspension displacement across varying road profiles. The intelligent adaptation of control parameters enhances the system's responsiveness, leading to improved ride comfort and reduced occupant fatigue. Therefore, integrating fuzzy logic with PID control provides a viable solution for optimizing semi-active seat suspension performance under diverse operating conditions.

5.1 System Controllers

Variable damper actuators play an important role in vibration management in a vehicle's semi-active seat suspension. The semi active damping control in automobiles improves comfort and safety. The system's core component is the semi-active damping which is connected to the sensors for input values. Based on that feedback, the semi-active control unit improves comfort by reducing vibrations, particularly while off-road riding. The input signal is then analysed, processed using various rules, and returned as output. This output indicated a desirable active damper control force. Using the Fuzzy-PID model, the desired damper force was approximately achieved by the spring or damper components using the computed input signal. The model controller received inputs for the desired damper force and velocity across the damper. The input signal was then analysed, processed using various rules, and returned as output. The control models' outputs were control signals given to the damper, which replicated the desired control force in the semi-active seat suspension system. The current research employed two types of controllers: PID and Fuzzy-PID. Figure 5.1 depicts the flow diagram for variable damping in seat suspension.

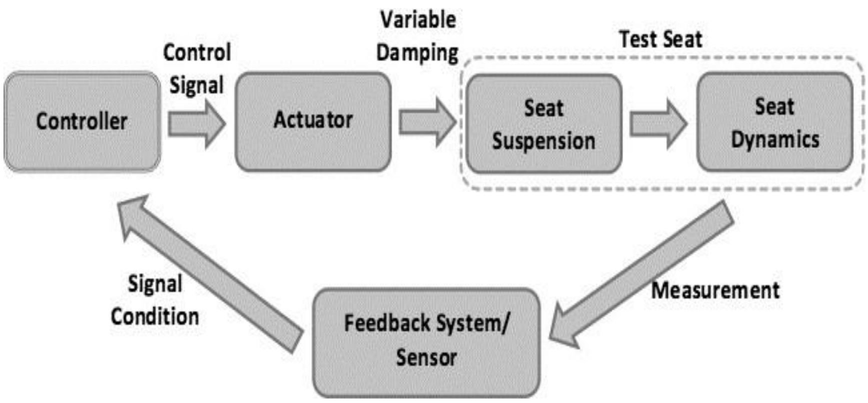


Figure 5.1 Flow diagram for execution of variable damping

5.2 PID control System

Proportional, integral and derivative functions make up PID controllers. Proportional uses the system to bring deviations into the control state. When a system is static, Integral employs calibration to improve its control precision. By adjusting for system deviations, the derivative is meant to increase the stability, sensitivity, and accuracy of the control. 5.2 illustrates the PID controls basic idea.

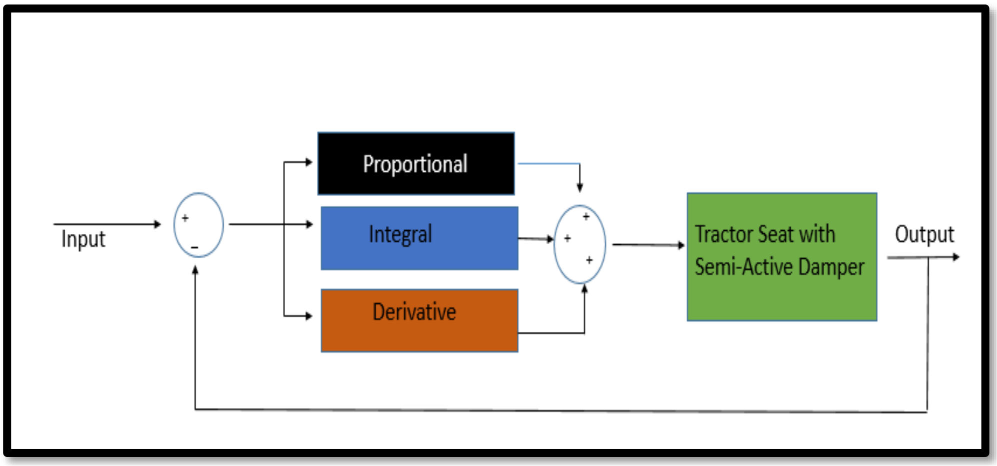


Figure 5.2 PID Controller

Controlling the driver's seat vertical acceleration is the aim of this PID control study. The difference between the controlled object's real and pre-set values is used as input. The damping force is adjusted to keep it under control [177].

5.3 Fuzzy-PID Control System

Because the seat suspension system is nonlinear and time-varying, the PID controller's inability to dynamically modify the parameters is a drawback. To create a composite controller for system control, PID control is generally integrated with other intelligent control systems. In this study, fuzzy and PID control are combined to form a fuzzy-PID controller, as shown in Figure 5.3.

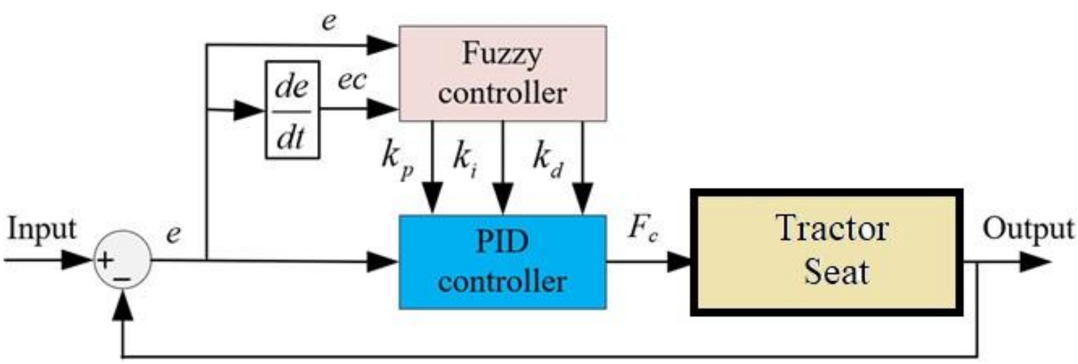


Figure 5.3 Fuzzy- PID Controller

In their study, Chen et al. (2022) implemented fuzzy control to dynamically adjust the parameters of the PID controller, aiming to better address the nonlinear characteristics of semi-active seat suspension systems and thus achieve superior control performance. The Fuzzy-PID controller utilizes the seat's vertical acceleration (denoted as \(e \)) and its rate of change (\(ec \)) as input variables. These inputs help determine the adjustments needed for the PID controller's parameters: \(Dkp \), \(Dki \), and \(Dkd \). These parameters are then calculated by the PID controller to achieve the optimal damping force for the damper [110].

The simulation results for the passive seat suspension system showed that the seat vertical acceleration \(e \) typically ranges between -2.5 and 2.5 m/s\(^2\). The fuzzy logic controller designed by the researchers includes two input variables and three output variables, each defined by seven fuzzy linguistic variables: negative-big (NB), negative-medium (NM), negative-small (NS), zero (ZO), positive-small (PS), positive-medium (PM), and positive-big (PB). Triangular membership functions represent these fuzzy input and output variables, and the Mamdani method is used for fuzzy reasoning [138].

The control system comprises 75 defined rules, and the defuzzification of the results is performed using the centroid approach. This fuzzy controller is implemented using MATLAB software, as illustrated in Figure 5.4 of the study. This comprehensive approach helps fine-tune the PID control parameters, ensuring better handling of the semi-active seat suspension's nonlinearities and thus improving ride comfort.

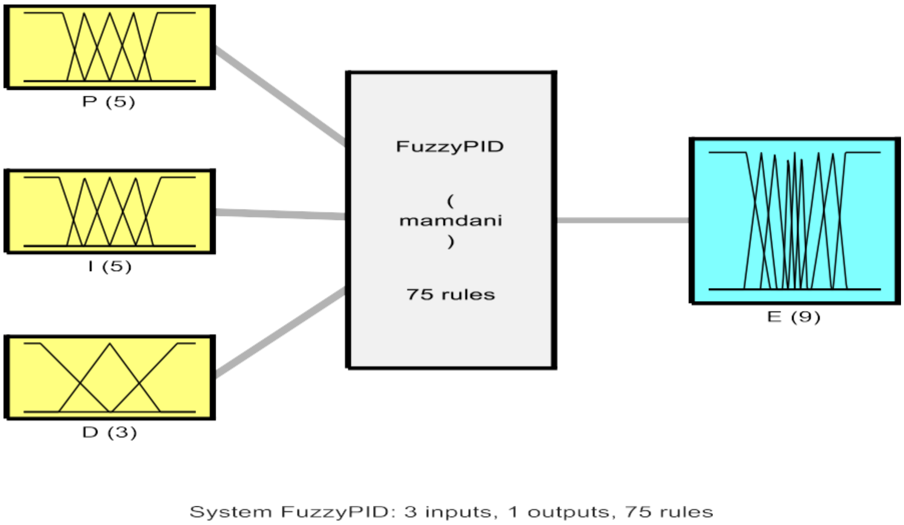


Figure 5.4 Fuzzy PID base rule

5.4 Numerical Simulations

The seat suspension system's accelerations were evaluated to determine its performance. This section presents the simulation results for the tractor seat's displacement, velocity, and acceleration. The Matlab programme for simulation of tractor with passive, Fuzzy-PID and PID controllers is given in Appendix B.

5.4.1 Performance of Designed Controllers

The analysis of the designed controller for ride comfort involves evaluating two key aspects: the root mean square (RMS) value of seat accelerations and the mode shapes at critical frequencies.

1. RMS Value of Seat Accelerations:

The RMS value of seat accelerations provides a measure of the overall vibration experienced by the occupant. Lower RMS values indicate reduced vibration transmission to the occupant, which correlates with improved ride comfort. By analyzing the RMS values, we can assess how effectively the controller minimizes vibrations and enhances comfort during vehicle operation [115].

An evaluation of the performance of the designed controllers in comparison to the passive system is presented here. In order to analyse and compare the output responses of semi active and passive tractor seat suspension system, the criterion to be implemented for performance index calculations is given as following:

$$Improvement\ (\%) = \left|\frac{Semiactive\ RMS\ value - Passive\ RMS\ value}{Passive\ RMS\ value}\right| \times 100 \tag{5.1}$$

The root-mean-square (RMS) values of the simulation results for irregular step road input were computed for ride comfort analysis.

5.4.1.1 Time Domain Analysis

The findings obtained in the passive and regulated seat suspensions for each controller were analysed using amplitude and frequency measurements. The power spectral density graphs depicted the frequency domain results, whilst the RMS values displayed the time domain results. When evaluating the seat suspension system, driving comfort was determined to be the most essential feature. In order to determine the vibration levels at the tractor seat, time domain analysis was performed using numerical simulations. Figure 5.5 depicts the tractor's chassis displacement due to step input disturbance.

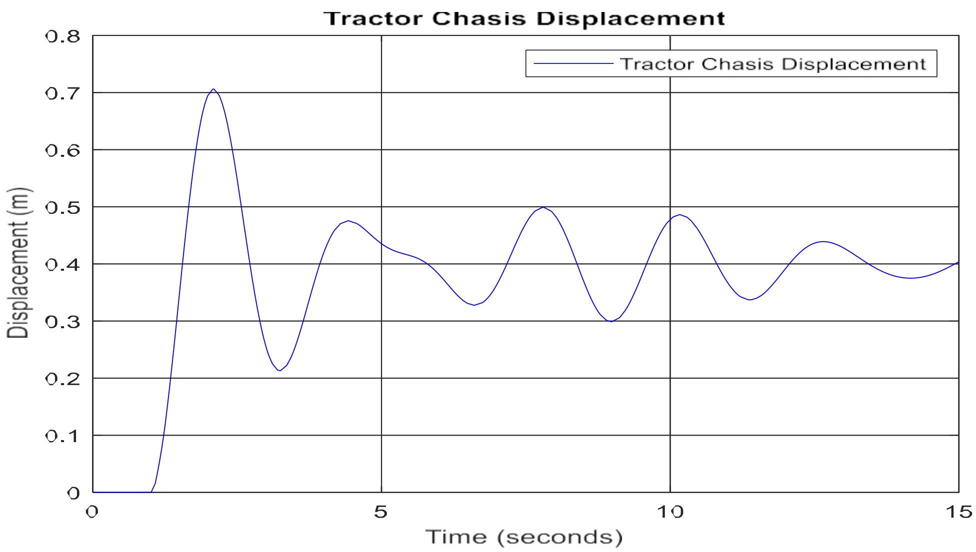


Figure 5.5 Chassis Displacement of Tractor

The RMS values of seat displacement, velocity, and accelerations for Passive, PID, and Fuzzy-PID controllers were calculated using Matlab in the ensuing phase using the modelled step input disturbances, and the results are displayed in Figures 5.6 to 5.8.

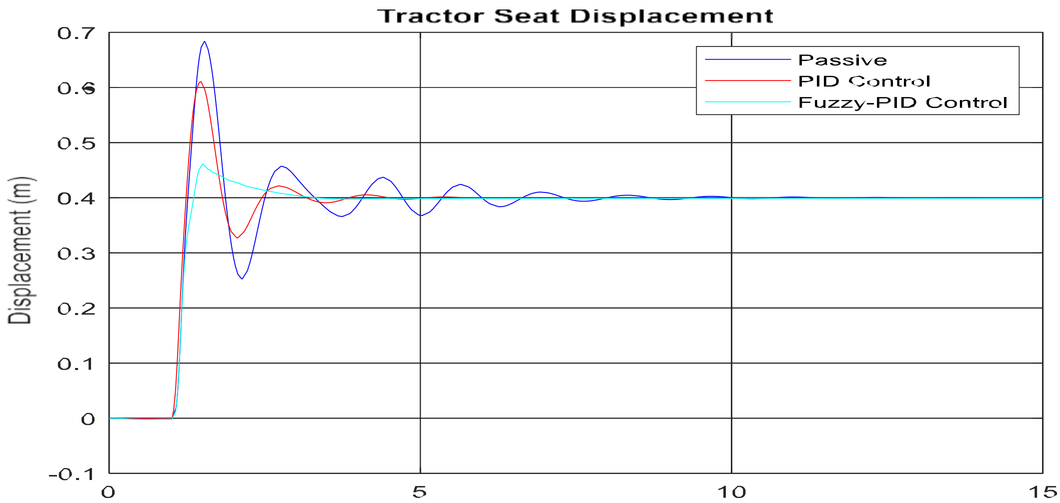


Figure 5.6 Tractor Seat Displacement

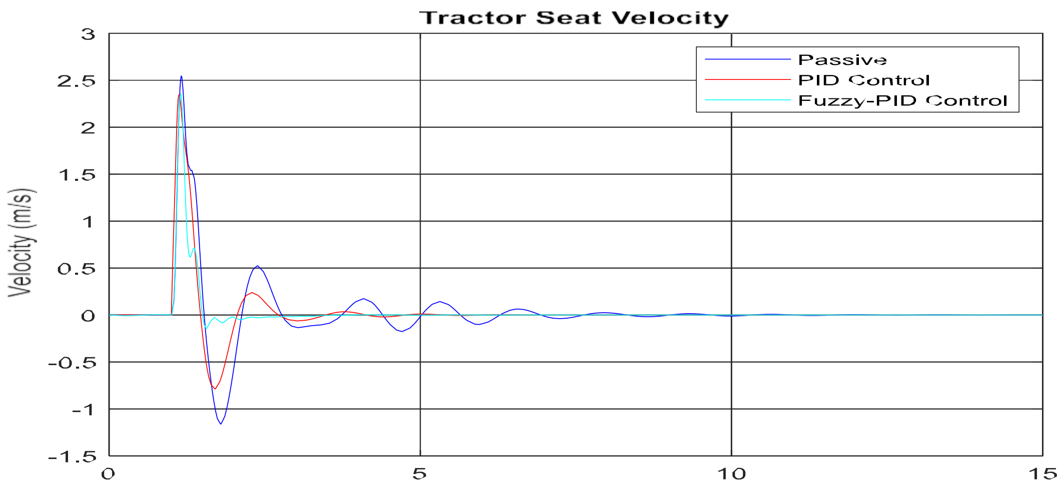


Figure 5.7

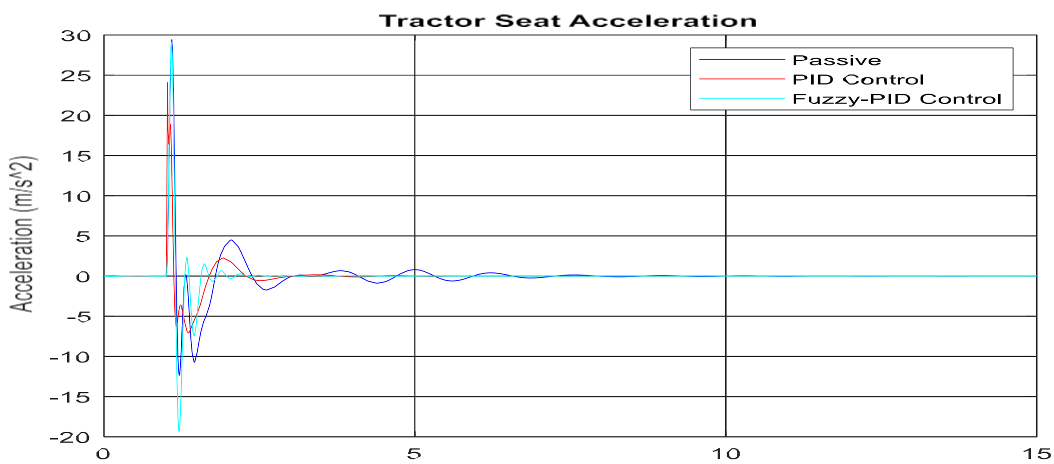


Figure 5.8 Tractor Seat Acceleration

Table 5.1 also includes data on seat accelerations. To measure this comparison, the percentage increase in riding comfort is considered.

Table 5.1. Simulation RMS results of seat accelerations

Tillage Implemen Type	Tractor Forward Speed	System	Seat Acceleration (RMS values, m/s^2)	Percentage improvement w.r.t Passive System
Cultivator	**2.30 Km/hr**	Passive	1.213615	---
		PID	0.880923	27.41
		Fuzzy-PID	0.742339	38.83
	4.20 Km/hr	Passive	1.413615	---
		PID	1.000124	29.25
		Fuzzy-PID	0.824933	41.64
	6.50 Km/hr	Passive	1.625321	---
		PID	1.101124	32.25
		Fuzzy-PID	0.901023	44.56
Disc Harrow	**2.30 Km/hr**	Passive	2.224153	---
		PID	1.705094	23.34
		Fuzzy-PID	1.340035	39.74
	4.20 Km/hr	Passive	2.865342	---
		PID	2.190076	30.36
		Fuzzy-PID	1.523629	46.82
	6.50 Km/hr	Passive	3.014541	---
		PID	2.026545	32.77
		Fuzzy-PID	1.411432	53.17

From table 5.1, it can be observed that RMS values of seat accelerations at tractor forward speed of 2.30 Km/hr with cultivator as tillage implement are reduced by 27.41% with PID controller and 38.83% with Fuzzy-PID controller as compared to passive seat suspension system. Corresponding values for disc harrow as tillage implement are 23.34% with PID controller and 39.74% with Fuzzy-PID controller as compared to passive suspension system. RMS values of seat accelerations have also been presented at forward tractor speeds of 4.20 Km/hr and 6.50 Km/hr. These results unequivocally demonstrate that, by lowering the tractor seat's acceleration level, the suggested Fuzzy-PID seat suspension performs better than both the uncontrolled and PID controllers. This suggests that the suggested solution offers a noticeable improvement in the tractor operator's riding comfort.

5.4.1.2 Peak-to- Peak Values Analysis

After analysing the RMS acceleration, the proposed seat suspension system is evaluated by comparing the peak-to-peak values of the PID and Fuzzy-PID control systems to the passive system. Table 5.3 displays the percentage reduction in peak-to-peak tractor seat acceleration measurements.

Table 5.2. Peak to peak values for tractor seat

Tillage Implemen Type	Tractor Forward Speed	Control System	Peak-to-Peak Value	Percentage improvement w.r.t Passive System
Chisel Plough	2.30 Km/hr	Passive	2.372	---
		PID	1.280	46.04
		Fuzzy-PID	1.018	57.08
	4.20 Km/hr	Passive	3.526	---
		PID	2.043	42.06
		Fuzzy-PID	1.798	49.00
	6.50 Km/hr	Passive	4.074	---
		PID	2.543	37.58
		Fuzzy-PID	2.234	45.16
Disc Harrow	2.30 Km/hr	Passive	3.671	---
		PID	2.121	42.22
		Fuzzy-PID	2.007	45.32
	4.20 Km/hr	Passive	4.685	---
		PID	2.990	36.18
		Fuzzy-PID	2.723	41.87
	6.50 Km/hr	Passive	5.657	---
		PID	3.796	32.89
		Fuzzy-PID	3.471	38.64

Table 5.3 shows that, compared to the passive seat system, the peak-to-peak values of the tractor seat are reduced by 46.04% with the PID controller and 57.08% with the Fuzzy-PID controller at a tractor forward speed of 2.30 km/hr with chisel plough. Table 5.3 also includes corresponding values for forward speeds of 4.20 km/hr and 6.50 km/hr with a disc harrow as the tillage equipment. As a result, as compared to PID and passive seat

suspension systems, the Fuzzy-PID control technique reduces peak-to-peak values more effectively.

5.4.1.3 Frequency Domain Analysis

Figure 5.9 shows the power spectral density (PSD) of the wheeled farm tractor operator seat during tillage operation and the step disturbance is caused by road excitation.

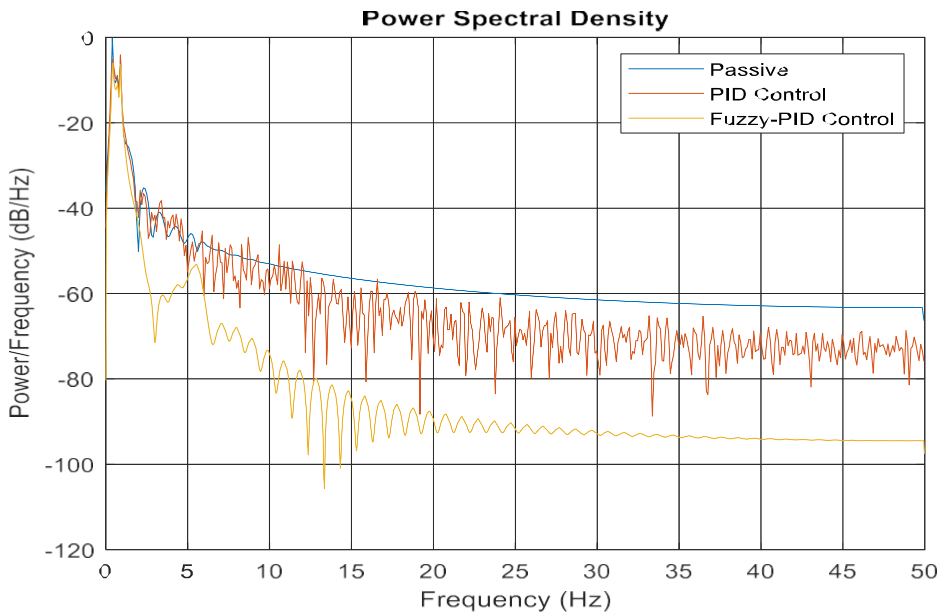


Figure 5.9. Passive frequency response of the tractor seat

The vibration characteristics of the seat suspension system bandwidth over a broad frequency range were evaluated using the PSD plots. One of the main objectives of using a suggested fuzzy controller for semi-active seat suspension was to lessen tractor seat vibrations, specifically in the low frequency range of 0 to 4Hz. A seat suspension system with neural fuzzy control produced a notable reduction in frequency peaks between 0 and 4 Hz. The fuzzy control seat suspension is the most effective in reducing acceleration in the 0-5 Hz band, as shown in figure 5.9, which is consistent with the fact that low frequency vibrations in the 0-6 Hz range have the greatest impact on human health [22].

5.5 Summary of Simulation Results

Figure 5.10 shows the summary findings of the test tractor seat accelerations for each regulated and uncontrolled seat suspension based on the numerical simulation.

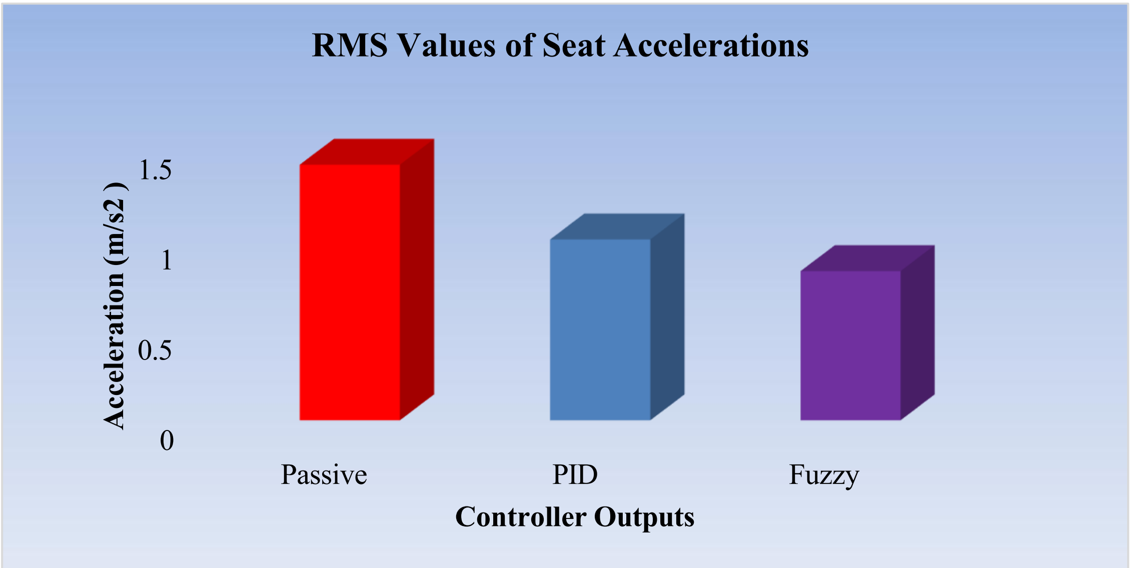


Figure 5.10. Comparison results of the tractor seat accelerations

The main goals of utilising a fuzzy-PID controller for tractor seat suspensions were to increase operator safety and lessen operator fatigue, with driver comfort coming in second. The suggested fuzzy-controlled seat suspension system's performance was evaluated by utilising the maximum overshoot for both seat acceleration and displacement as a quantifier parameter. The comparison of the maximum overshoot outcomes for the PID, fuzzy, and passive control strategies concluded this section. The maximum tractor seat overshoot for acceleration obtained by numerical simulation is summarised in Figure 5.11.

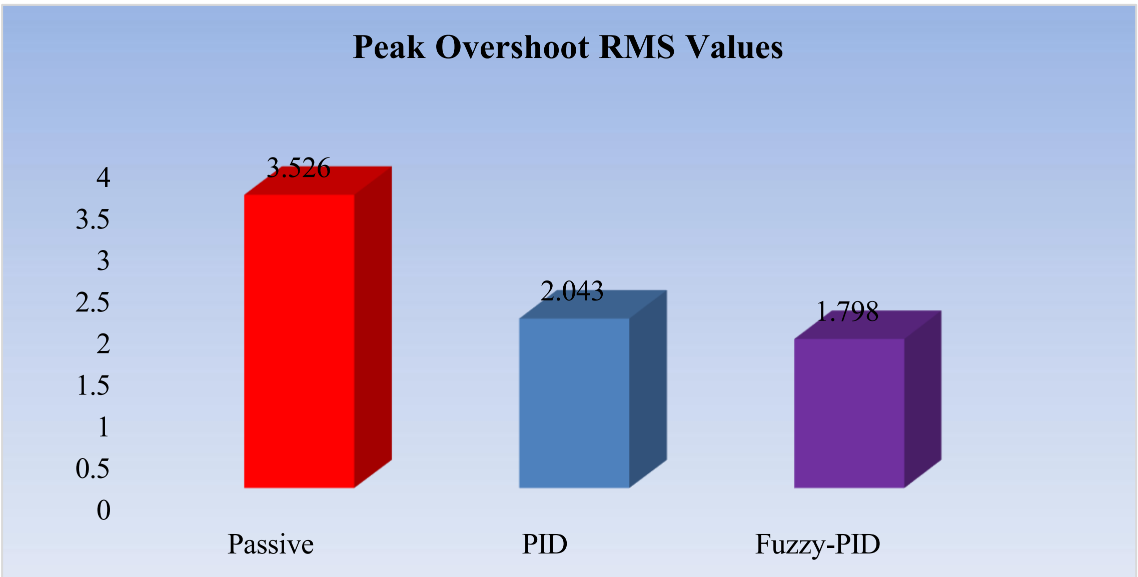


Figure 5.11. Charts comparing maximum overshoot results of tractor seat acceleration

2. Mode Shapes at Critical Frequencies:

Mode shapes represent the spatial distribution of vibrations in the system at specific frequencies. Analyzing mode shapes at critical frequencies helps identify vibration patterns that may cause discomfort to the occupant. By understanding these mode shapes, adjustments can be made to the controller parameters to target and mitigate vibrations that contribute to discomfort, thereby improving ride comfort.

To calculate the mode shapes at critical frequencies, we need to define the mass, stiffness, and damping matrices of the system based on the provided parameters. Then, we can use MATLAB to perform modal analysis. MATLAB Code for mode shapes is given in Appendix C.

This MATLAB code constructs the mass, stiffness, and damping matrices based on the given parameters and then performs modal analysis to calculate mode shapes and frequencies. The mode shapes represent the spatial distribution of vibration patterns in the system at specific frequencies.

Mode Shapes:

```
1.0000   -0.0083    1.0000

0.9917    1.0000    1.0000

0.3400    0.3429    1.0000
```

Frequencies (Hz):

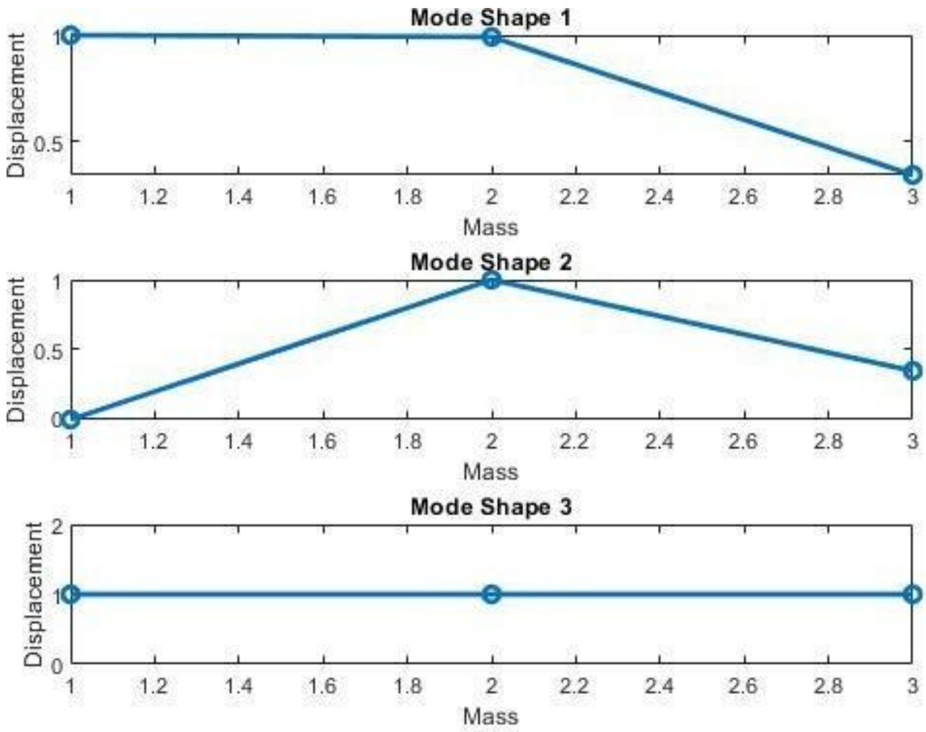
```
0.0000 + 0.2994i

3.2947 + 0.0000i

0.0000 + 0.0000i
```

Each column of the mode shapes matrix represents a mode shape corresponding to a particular natural frequency. The values in each column indicate the relative displacements of the masses (wheel, tractor, and seat) in the system.

The frequencies represent the natural frequencies of the system in Hertz (Hz). The frequencies are complex numbers, where the real part represents the frequency in Hz, and the imaginary part represents the damping ratio. In this case, the first and third modes have a non-zero imaginary part, indicating that they are damped modes, while the second mode is undamped.



The image shows the mode shapes of a three-degree-of-freedom (3-DOF) system. These mode shapes represent the relative displacements of the masses in each mode of vibration. Here is a brief explanation of each mode shape depicted in the plots:

Mode Shape 1: This is the first mode of vibration. The displacements of all three masses are in phase and move together with the same amplitude. This mode shape typically corresponds to the lowest natural frequency. In this plot, the displacements of the masses are equal, indicating synchronous motion.

Mode Shape 2: This is the second mode of vibration. The displacement of the middle mass (mass 2) is larger than those of the end masses (masses 1 and 3), and the end masses move in opposite directions. This indicates a higher frequency of vibration compared to the first mode. This mode shape shows a node (point of zero displacement) in between the first and third masses, where mass 2 reaches maximum displacement.

Mode Shape 3: This is the third mode of vibration. The displacements of the first and third masses are equal but opposite in direction, while the middle mass (mass 2) remains stationary. This mode shape corresponds to an even higher frequency of vibration than the first and second modes. The middle mass acts as a node, and the end masses have maximum, but opposite, displacements.

These mode shapes represent the natural vibration patterns of a mechanical system with three degrees of freedom. In each mode shape, the system oscillates at a specific frequency, and the displacement of each mass varies accordingly. The first mode shape generally represents the fundamental frequency, where the entire system moves in phase. The second and third mode shapes represent higher frequencies with more complex patterns of motion.

These mode shapes are important in understanding the dynamic behavior of the system, including how it will respond to different frequencies of excitation.

5.6 Validation of Simulation Results

As the simulation results have shown a notable reduction in the seat vibrations, next step was to validate the simulation results experimentally. Both seat base and back forms single unit and are supported by springs and damper to provide the damping effect. The original seat suspension system was consist of two springs and one hydraulic damper. The all parts of the tractor seat was disassembled and the basic parts of tractor seat in the disassembled form are shown below. Figure 5.12 (a) shows the original seat with back cover open to make the suspension components (springs and damper) clearly visible.

(a)

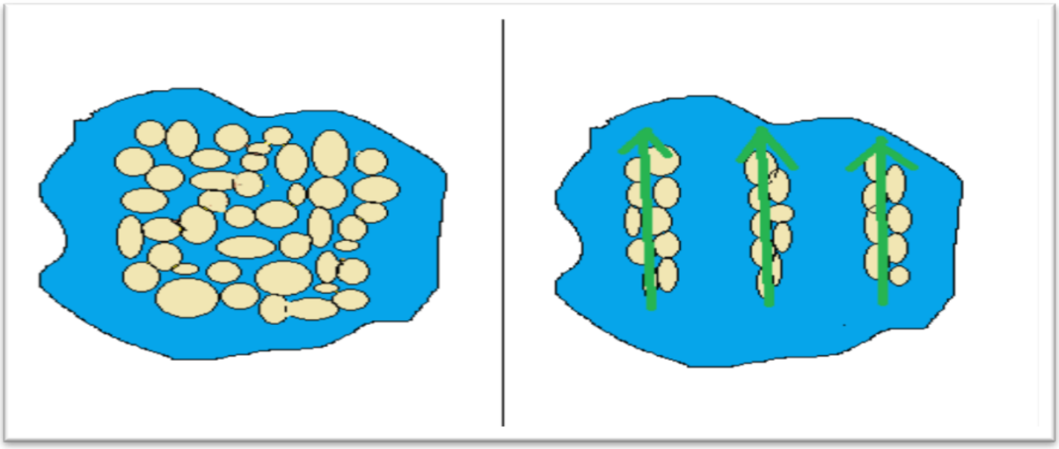
Figure 5.12 (b) shows all of the tractor seat's suspension parts disassembled, while figure 5.12 (c) shows an expanded view of the tractor seat's suspension parts.

(b) **(c)**

Figure 5.12. (a) Original tractor seat with back cover open (b) removed parts of the seat (c) enlarged view of the suspension parts

5.6.1. Redesigning of tractor seat

In the redesigning of seat the hydraulic damper in tractor seat was to be replaced with MR damper. A Magneto-rheological (MR) are used as semi active control device. Construction of MR dampers is similar to viscous dampers. The viscous dampers use hydraulic oil whereas the MR dampers are working on MR fluids. The MR fluids are made up of micron-sized magnetically polarizable particles distributed in a carrier media like mineral oil or silicone oil. In MR damper an electronic circuit is internally mounted by copper windings along with MR fluid. The effectiveness of MR damper is greatly affected by command voltage to the copper windings [185]. Command voltage and excitation frequency are two major factors in MR dampers. In the present case the voltage was regulated from 1V to 8V. A digital multi-meter and a voltage regulator having 0 – 10 voltage range are used for regulating the voltage [193]. These electronic devices are used for applying a command voltage to the MR Damper. Figure 5.13 explains MR fluid for two conditions (a) without application of charge and (b) with application of charge.



(a) (b)

Figure 5.13. Fluid action in MR Damper (a) without applicationof charge (b) with the application of charge.

The technical specifications of the MR damper are represented in table 5.3

Table 5. 3. Technical specification of MR damper

Sr. No.	Description	Value
1.	Appearance	Dark grey liquid
2.	Density g/cm^3	2.40-2.50
3.	Operating Temperature Range	-20 to + 150 C
4.	Max yield stress @ 140 KA/m	60Kpa
5.	Viscosity	0.650
6.	Flash Point	>180 C
7.	Power Requirements	2-24V, 0.5-2A
8.	Height of Piston Assembly	182 mm
9.	Height of MR Damper Assembly	199 mm
10.	Diameter of Damper	27mm

Schematic diagram of MR damper is represented in figure 5.14

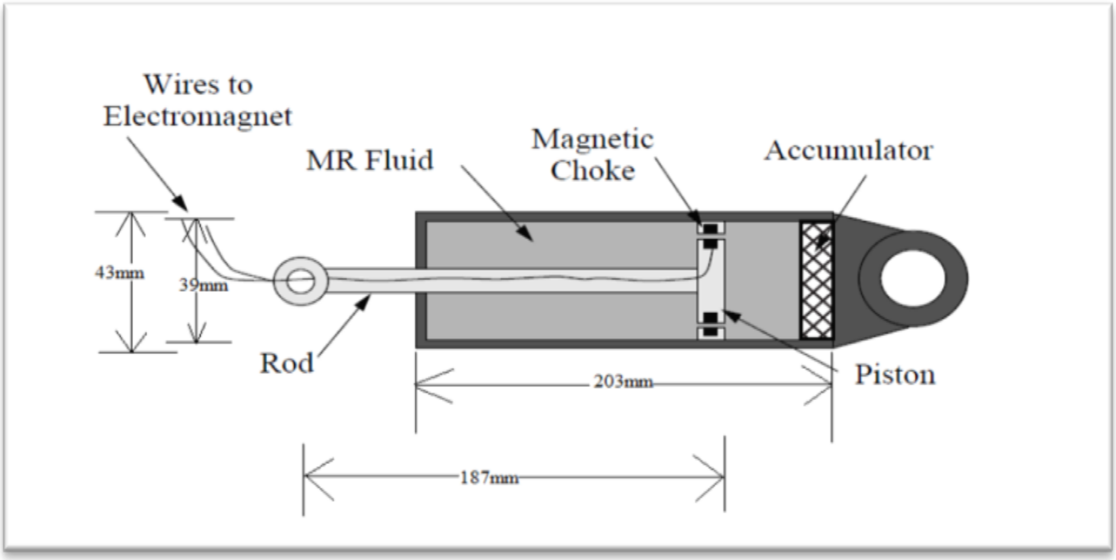
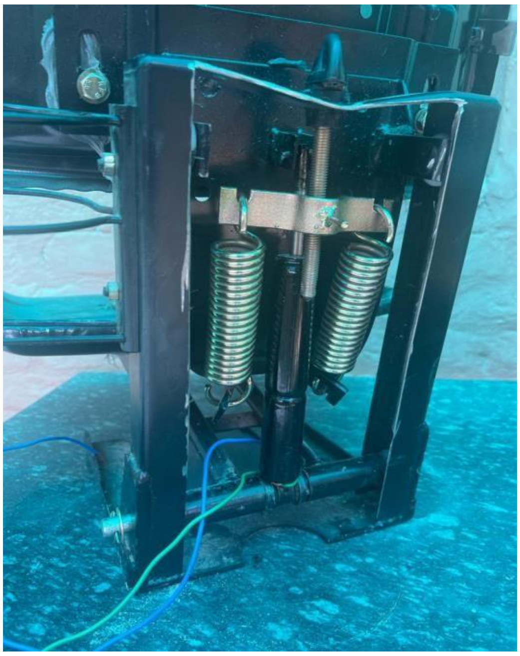


Figure 5.14. Schematic Diagram of MR Damper.

This MR damper was chosen according to the stroke of the piston of the hydraulic damper and the overall height of the damper assembly so that it can be easily fit into the existing system. The MR damper selected for the present work has been shown in figure 5.15 (a). The position of the MR damper in the tractor seat suspension is represented in figure 5.15 (b).

(a)



(b)

Figure 5.15. (a) MR Damper (b) Position of MR damper fitted in the seat.

The seat was fitted to tractor again and experiment was carried out with same input parameters in terms of forward speed and type of tillage equipments as that was carried out for passive suspension system. Accelerations at the base of the redesigned seat were recorded at three different forward speeds and with two different types of tillage equipment.

The results obtained for lateral direction of seat accelerations with PID and Fuzzy controller for chisel plough and disc harrow has been expressed in the table 5.4 and table 5.5 respectively.

Table 5.4. Results for chisel plough at forward speed of 2.30 Km/hr in lateral direction

System	Conventional Seat Accelerations [Simulated] (RMS values, mm/s^2)	Modified Seat Accelerations [Experimental] (RMS values, mm/s^2)	Percentage Variation
Passive	0.4706		-----
PID	0.3433	0.361	0.017
Fuzzy Logic	0.1036	0.1562	0.0526

Table 5.5. Results for disc harrow at forward speed of 2.30 Km/hr in lateral direction

System	Conventional Seat Accelerations[Simulated] (RMS values, mm/s^2)	Modified Seat Accelerations[Experimental] (RMS values, mm/s^2)	Variation in simulated and experimental results of modified seat (mm)
Passive	0.6706		-----
PID	0.5433	0.921	0.3777
PID-Fuzzy	0.3036	0.3426	0.039

The results has been validated experimentally and it could be understood from the results that PID -Fuzzy controllers controls the MR damper in tractor seat and reduce the vibrations to a notable values. There is some variation in the simulated and experimental results of the controller outputs.

CHAPTER 6

CONCLUSION AND SCOPE OF FUTURE WORK

The primary aim of this research was to improve the comfort of agricultural tractor operators by introducing PID and fuzzy controllers. To achieve this, a structured research methodology was developed, focusing on setting clear objectives to address existing knowledge gaps and achieve the study's goal. Through this process, a suitable method for seat suspension and damper control specific to tractor seats was identified. Subsequently, a tractor seat suspension system was constructed and tested using the identified controllers.

The performance evaluation of the proposed seat suspension system heavily relied on computer simulations, which were meticulously planned to conduct comprehensive assessment tests. During simulation testing, data on seat acceleration was collected and analyzed to determine vibration characteristics in both time and frequency domains. These findings were crucial for evaluating the comfort level of the tractor seat.

By following this systematic approach, the research significantly contributed to understanding seat suspension and damper control techniques tailored for agricultural tractors. Furthermore, the use of computer simulations enabled thorough evaluation and validation of the proposed system's effectiveness in enhancing operator comfort during tractor operation.

6.1 Conclusions

This study provides valuable insights into the implementation of semi-active seat suspension systems for agricultural tractors, particularly focusing on the effectiveness of PID and fuzzy controllers. Here's a summary of the main findings and recommendations for future work:

1. Semi-Active Seat Suspension:

The selection of a semi-active seat suspension system is predicated on its capability to modulate damping coefficients in real-time through adaptive control algorithms, thereby achieving an optimal trade-off between ride comfort and vehicular stability. The implementation of Fuzzy Logic Control (FLC) and Proportional-Integral-Derivative (PID) control strategies is underpinned by their superior adaptability in dynamically tuning damping forces in response to stochastic excitation inputs and transient operational perturbations. These control paradigms facilitate nonlinear compensatory adjustments, ensuring enhanced attenuation of vibratory energy across a broad spectrum of excitation frequencies while preserving system robustness. The synergistic integration of these methodologies optimizes the suspension's response characteristics, effectively mitigating whole-body vibration (WBV) exposure and maximizing biomechanical compliance under diverse operating conditions.

2. Modeling:

The formulation and rigorous validation of an intricate mathematical model are imperative for precisely characterizing the coupled dynamics of the tractor-seat system, encapsulating multi-domain interactions and nonlinear vibratory phenomena. Leveraging MATLAB-Simulink as a computational framework facilitates high-fidelity simulations, enabling parametric analyses and transient response evaluations under diverse operational scenarios. This approach elucidates the intricate interplay between the tractor chassis, implement-induced perturbations, and seat suspension dynamics, providing critical insights into system stability, resonance characteristics, and energy dissipation mechanisms. Such a robust simulation environment ensures the optimization of damping strategies and structural compliance, ultimately enhancing ride quality and mitigating whole-body vibration exposure.

3. Controller Effectiveness:

The empirical validation of the semi-active seat suspension system demonstrates significant enhancements in ride comfort and dynamic stability, affirming the superior regulatory capabilities of PID and fuzzy control architectures. The PID controller ensures precise modulation of damping forces through closed-loop error compensation, yielding high-frequency responsiveness and robust disturbance rejection. In contrast, the fuzzy logic controller exhibits exceptional proficiency in addressing system nonlinearities and parametric uncertainties, leveraging rule-based inference mechanisms for adaptive real-time adjustments. The synergistic integration of these control strategies optimally modulates vibratory energy dissipation, thereby mitigating whole-body vibration effects and enhancing operator ergonomics in dynamic tractor-seat interactions.

4. Vibration Reduction:

The substantial attenuation of seat vibrations within the critical 0–4 Hz frequency domain highlights the efficacy of the semi-active suspension system in suppressing low-frequency oscillatory disturbances. This attenuation is paramount in minimizing biomechanical resonance effects, which are strongly correlated with operator discomfort, fatigue accumulation, and long-term musculoskeletal health implications. By dynamically modulating damping characteristics in response to real-time vibratory inputs, the system effectively mitigates sustained exposure to deleterious low-frequency excitations. The resultant reduction in transmissibility of vibrational energy enhances ride quality and operational ergonomics, thereby optimizing human-vehicle interaction dynamics and mitigating adverse physiological impacts associated with prolonged vehicular operation.

5. Acceleration Reduction:

The pronounced attenuation of tractor seat acceleration achieved through the fuzzy-controlled suspension system underscores its capability to optimize ride dynamics by minimizing high-frequency perturbations and transient shocks. This advanced control methodology effectively mitigates vibrational energy transmission to the operator, thereby enhancing biomechanical comfort and reducing physiological stressors associated with prolonged vehicular operation. By dynamically adjusting damping characteristics in response to real-time disturbances, the system ensures superior vibration isolation, leading to a perceptibly smoother ride experience. The resultant improvement in operator comfort directly correlates with enhanced cognitive focus, reduced neuromuscular fatigue, and increased operational efficiency, ultimately contributing to sustained productivity in extended-duty cycles.

This investigation presents an exhaustive analysis of the performance enhancements and biomechanical implications associated with the integration of semi-active seat suspension systems governed by PID and fuzzy control architectures in agricultural tractors. The findings elucidate critical advancements in ride dynamics, vibration attenuation, and adaptive damping mechanisms, offering a robust framework for future research in precision-tuned vehicular ergonomics. These insights serve as a foundational reference for the progressive refinement of suspension topologies, fostering the development of next-generation tractor systems optimized for superior operator comfort, operational stability, and long-term musculoskeletal health.

6.2 Recommendations for Future work

1. **Comparative Analysis:** Conduct comparative frequency spectrum analysis for plowing operations and different field conditions with varying moisture contents.
2. **Exploration of Modern Control Strategies:** Explore other modern control strategies besides PID and fuzzy-PID controllers to further improve ride acceleration using optimal control.
3. **Variation in Tyre Pressure:** Study the impact of varying tyre pressure on ride comfort for the driver.
4. **Diverse Tractor Models:** Extend the study to include different makes and models of tractors to assess the generalizability of findings.
5. **Multiple Implements:** Conduct experiments with more tillage implements to evaluate system performance under diverse operating conditions.
6. **Transport Conditions:** Investigate ride comfort while tractors are used on smooth roads for transportation purposes with trailers.
7. **Road Disturbance Prediction:** Explore vibration control by predicting road disturbances ahead of time using cameras mounted in the vehicle.

These recommendations offer avenues for further research and development to enhance the effectiveness and applicability of semi-active seat suspension systems in agricultural tractors, ultimately improving operator comfort and productivity.

LIST OF PUBLICATIONS

1. “Tractor Seat Vibration Analysis during Tillage with Implements” in *International Journal of Mechanical Engineering* **(Scopus Indexed)** Vol 6, No. 3, 2021.

2. “Tractor Seat Vibration optimization with Active Control System during Tillage using Modelling and Simulation in Ansys” in *International Journal of Intelligent Systems and Applications in Engineering* **(Scopus Indexed)** Vol 12 (4s) 2024.

3. “Modeling, Simulation and Optimization of Agricultural Tillage Process Vibrations using an Interactive Active Control System” in *E3S Web of Conferences* **(Scopus Indexed)** Vol 430, 2023.

4. “Development of Dynamic Model of Tractor for Vibration Analysis of Operator’s Seat” to International Conference on Advances in Material Science and Technology held at Lovely Professional University- *AIP Proceedings* **(Scopus Indexed)** Vol 2962, No. 1, 2024.

5. “Ride Comfort Enhancement for Tractor Drivers during Tillage in Agricultural Field using Semi Active Suspension for seat” – *IEEE Xplore* **(Scopus Indexed)** 2024.

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Appendix A
Experimental Data for Tractor Seat base

Time(min|sec)	X axis(g)	Y axis(g)	Z axis(g)	Xaxis	Yaxis	Z axis
53|43	-0.07	-0.02	-0.17	-0.7	-0.2	-1.7
53|43	0	-0.02	-0.17	0	-0.2	-1.7
53|43	-0.02	0.07	-0.04	-0.2	0.7	-0.4
53|43	-0.02	0.19	0.14	-0.2	1.9	1.4
53|43	0.02	0.14	-0.12	0.2	1.4	-1.2
53|43	0.12	-0.02	-0.14	1.2	-0.2	-1.4
53|43	0.02	-0.07	-0.04	0.2	-0.7	-0.4
53|43	-0.07	-0.09	0.02	-0.7	-0.9	0.2
53|43	-0.02	-0.14	-0.19	-0.2	-1.4	-1.9
53|43	-0.17	-0.21	-0.19	-1.7	-2.1	-1.9
53|43	-0.07	-0.39	-0.21	-0.7	-3.9	-2.1
53|43	0.26	-0.48	-0.24	2.6	-4.8	-2.4
53|43	0	-0.31	0.19	0	-3.1	1.9
53|43	-0.21	-0.21	0.41	-2.1	-2.1	4.1
53|43	-0.19	-0.29	0.21	-1.9	-2.9	2.1
53|43	-0.07	-0.46	0.09	-0.7	-4.6	0.9
53|43	0.02	-0.46	-0.04	0.2	-4.6	-0.4
53|43	0.14	-0.31	0.02	1.4	-3.1	0.2
53|43	0	-0.07	0.19	0	-0.7	1.9
53|43	-0.19	0.04	0.24	-1.9	0.4	2.4
53|43	-0.26	-0.04	0	-2.6	-0.4	0
53|43	-0.14	-0.07	-0.04	-1.4	-0.7	-0.4
53|43	0	0.04	-0.04	0	0.4	-0.4
53|43	0.09	0.31	0.24	0.9	3.1	2.4
53|43	0.07	0.48	0.46	0.7	4.8	4.6
53|43	-0.04	0.39	0.43	-0.4	3.9	4.3
53|43	-0.17	0.04	0.41	-1.7	0.4	4.1
53|43	-0.19	-0.14	0.19	-1.9	-1.4	1.9
53|43	-0.14	-0.21	0.24	-1.4	-2.1	2.4
53|43	-0.02	-0.04	0.14	-0.2	-0.4	1.4
53|43	-0.02	0.09	0.34	-0.2	0.9	3.4
53|43	-0.04	0.14	0.24	-0.4	1.4	2.4
53|43	-0.12	0.04	0.17	-1.2	0.4	1.7
53|43	-0.12	-0.07	0.04	-1.2	-0.7	0.4
53|43	0	-0.19	-0.14	0	-1.9	-1.4
53|43	-0.02	-0.14	-0.21	-0.2	-1.4	-2.1
53|43	0	-0.12	0.07	0	-1.2	0.7
53|43	-0.04	-0.09	0.04	-0.4	-0.9	0.4

53|43	-0.07	-0.14	-0.02	-0.7	-1.4	-0.2
53|43	-0.07	-0.12	-0.07	-0.7	-1.2	-0.7
53|43	-0.02	-0.14	-0.12	-0.2	-1.4	-1.2
53|43	-0.04	-0.07	-0.02	-0.4	-0.7	-0.2
53|43	-0.09	-0.04	-0.02	-0.9	-0.4	-0.2
53|43	-0.12	-0.04	0.04	-1.2	-0.4	0.4
53|43	-0.07	-0.09	0.02	-0.7	-0.9	0.2
53|43	0.09	-0.04	-0.19	0.9	-0.4	-1.9
53|43	0.04	0.09	0	0.4	0.9	0
53|43	-0.09	0.19	0.07	-0.9	1.9	0.7
53|43	-0.07	0.17	-0.04	-0.7	1.7	-0.4
53|43	-0.09	0.07	-0.12	-0.9	0.7	-1.2
53|43	-0.12	0.04	0.04	-1.2	0.4	0.4
53|43	0.02	0.04	-0.12	0.2	0.4	-1.2
53|43	0	0.14	-0.09	0	1.4	-0.9
53|43	-0.12	0.17	0	-1.2	1.7	0
53|43	-0.14	0.04	-0.04	-1.4	0.4	-0.4
53|43	-0.02	-0.07	-0.14	-0.2	-0.7	-1.4
53|43	0	0.02	-0.04	0	0.2	-0.4
53|43	-0.02	0.09	0.09	-0.2	0.9	0.9
53|43	-0.02	0.19	0	-0.2	1.9	0
53|43	-0.02	0.07	-0.24	-0.2	0.7	-2.4
53|43	-0.04	-0.04	-0.21	-0.4	-0.4	-2.1
53|43	0.07	-0.17	-0.43	0.7	-1.7	-4.3
53|43	0.12	-0.17	-0.39	1.2	-1.7	-3.9
53|43	-0.14	-0.17	0.02	-1.4	-1.7	0.2
53|43	-0.21	-0.31	-0.02	-2.1	-3.1	-0.2
53|43	-0.04	-0.48	-0.14	-0.4	-4.8	-1.4
53|43	-0.04	-0.53	-0.02	-0.4	-5.3	-0.2
53|43	-0.02	-0.43	0.02	-0.2	-4.3	0.2
53|43	0	-0.29	0.12	0	-2.9	1.2
53|43	-0.04	-0.24	0	-0.4	-2.4	0
53|43	-0.12	-0.29	0.09	-1.2	-2.9	0.9
53|43	-0.12	-0.41	0.07	-1.2	-4.1	0.7
53|43	-0.04	-0.31	0	-0.4	-3.1	0
53|43	-0.04	-0.09	0.09	-0.4	-0.9	0.9
53|43	-0.09	0.14	0.04	-0.9	1.4	0.4
53|43	-0.14	0.17	0.14	-1.4	1.7	1.4
53|43	-0.09	0.14	0.02	-0.9	1.4	0.2
53|43	0	0.09	0.12	0	0.9	1.2
53|43	0.07	0.19	0.19	0.7	1.9	1.9
53|43	-0.02	0.24	0.48	-0.2	2.4	4.8
53|43	-0.14	0.19	0.51	-1.4	1.9	5.1

53|43	-0.12	0.02	0.36	-1.2	0.2	3.6
53|43	-0.14	-0.04	0.26	-1.4	-0.4	2.6
53|43	-0.07	-0.04	0.14	-0.7	-0.4	1.4
53|43	-0.02	0.04	0.19	-0.2	0.4	1.9
53|43	-0.02	0.09	0.24	-0.2	0.9	2.4
53|43	-0.12	0.02	0.24	-1.2	0.2	2.4
53|43	-0.09	-0.09	0.09	-0.9	-0.9	0.9
53|43	-0.07	-0.19	-0.07	-0.7	-1.9	-0.7
53|43	-0.04	-0.14	0	-0.4	-1.4	0
53|43	0.02	-0.02	-0.02	0.2	-0.2	-0.2
53|43	0.04	0	-0.14	0.4	0	-1.4
53|43	-0.02	-0.04	0	-0.2	-0.4	0
53|43	-0.14	-0.14	0.04	-1.4	-1.4	0.4
53|43	-0.14	-0.21	-0.07	-1.4	-2.1	-0.7
53|43	-0.17	-0.24	-0.02	-1.7	-2.4	-0.2
53|43	-0.09	-0.19	-0.02	-0.9	-1.9	-0.2
53|43	-0.04	-0.09	0.04	-0.4	-0.9	0.4
53|43	-0.02	-0.02	0.02	-0.2	-0.2	0.2
53|43	0	0.07	0.02	0	0.7	0.2
53|43	-0.02	0.12	0.12	-0.2	1.2	1.2
53|43	-0.09	0.12	0.07	-0.9	1.2	0.7
53|43	-0.09	0.04	-0.07	-0.9	0.4	-0.7
53|43	-0.12	0.02	-0.12	-1.2	0.2	-1.2
53|43	-0.14	0.04	-0.12	-1.4	0.4	-1.2
53|43	-0.02	0.09	-0.19	-0.2	0.9	-1.9
53|43	-0.07	0.12	0.09	-0.7	1.2	0.9
53|43	-0.07	0.12	0.14	-0.7	1.2	1.4
53|43	-0.04	0.02	0.02	-0.4	0.2	0.2
53|43	-0.07	0.04	-0.07	-0.7	0.4	-0.7
53|43	-0.04	0.02	-0.09	-0.4	0.2	-0.9
53|43	-0.07	0.09	-0.12	-0.7	0.9	-1.2
53|43	-0.04	0.09	-0.02	-0.4	0.9	-0.2
53|43	0.02	0.07	-0.19	0.2	0.7	-1.9
53|43	0.12	-0.04	-0.31	1.2	-0.4	-3.1
53|43	0	-0.12	0.02	0	-1.2	0.2
53|43	0	-0.17	-0.17	0	-1.7	-1.7
53|43	-0.17	-0.26	-0.21	-1.7	-2.6	-2.1
53|43	-0.24	-0.39	-0.04	-2.4	-3.9	-0.4
53|43	-0.04	-0.51	-0.07	-0.4	-5.1	-0.7
53|43	0.14	-0.53	-0.04	1.4	-5.3	-0.4
53|43	0.04	-0.36	0.26	0.4	-3.6	2.6
53|43	-0.14	-0.04	0.43	-1.4	-0.4	4.3
53|43	-0.12	-0.29	0.19	-1.2	-2.9	1.9

53|43	-0.14	-0.41	0.02	-1.4	-4.1	0.2
53|43	-0.12	-0.46	-0.02	-1.2	-4.6	-0.2
53|43	-0.02	-0.31	0.07	-0.2	-3.1	0.7
53|43	0.09	-0.09	0.07	0.9	-0.9	0.7
53|43	-0.09	0.12	0.14	-0.9	1.2	1.4
53|43	-0.17	0.07	0.12	-1.7	0.7	1.2
53|43	-0.07	0.02	-0.02	-0.7	0.2	-0.2
53|43	-0.04	0.04	0.07	-0.4	0.4	0.7
53|43	-0.07	0.24	0.34	-0.7	2.4	3.4
53|43	0.02	0.34	0.36	0.2	3.4	3.6
53|43	0.07	0.31	0.24	0.7	3.1	2.4
53|43	0	0.19	0.34	0	1.9	3.4
53|43	-0.19	0.04	0.41	-1.9	0.4	4.1
53|43	-0.14	-0.04	0.21	-1.4	-0.4	2.1
53|43	-0.14	-0.09	0.21	-1.4	-0.9	2.1
53|43	-0.09	-0.04	0.26	-0.9	-0.4	2.6
53|43	-0.07	-0.02	0.24	-0.7	-0.2	2.4
53|43	0	0.02	0.04	0	0.2	0.4
53|43	-0.04	0.07	0.12	-0.4	0.7	1.2
53|43	-0.02	0	-0.04	-0.2	0	-0.4
53|43	0	-0.02	-0.12	0	-0.2	-1.2
53|43	-0.04	-0.17	-0.04	-0.4	-1.7	-0.4
53|43	-0.09	-0.21	-0.04	-0.9	-2.1	-0.4
53|43	-0.12	-0.29	0	-1.2	-2.9	0
53|43	-0.14	-0.26	0	-1.4	-2.6	0
53|43	-0.09	-0.19	-0.02	-0.9	-1.9	-0.2
53|43	-0.04	-0.17	-0.09	-0.4	-1.7	-0.9
53|43	-0.07	-0.09	0.12	-0.7	-0.9	1.2
53|43	-0.07	-0.02	0.09	-0.7	-0.2	0.9
53|43	0	0	0	0	0	0
53|43	-0.09	0.07	0.07	-0.9	0.7	0.7
53|43	-0.14	0.09	0.07	-1.4	0.9	0.7
53|43	-0.12	0.09	0.02	-1.2	0.9	0.2
53|43	0	0.04	-0.19	0	0.4	-1.9
53|43	-0.02	0.09	0.02	-0.2	0.9	0.2
53|43	-0.09	0.12	0.07	-0.9	1.2	0.7
53|43	-0.07	0.09	0.07	-0.7	0.9	0.7
53|43	-0.14	0.04	0	-1.4	0.4	0
53|43	-0.14	0.02	-0.02	-1.4	0.2	-0.2
53|43	-0.02	0	-0.17	-0.2	0	-1.7
53|43	0.04	0.07	-0.12	0.4	0.7	-1.2
53|43	-0.12	0.17	0.19	-1.2	1.7	1.9
53|43	-0.04	0.14	0	-0.4	1.4	0

53|43	0.12	0	-0.19	1.2	0	-1.9
53|43	0	-0.07	-0.09	0	-0.7	-0.9
53|43	-0.17	-0.04	-0.17	-1.7	-0.4	-1.7
53|43	-0.12	-0.14	-0.31	-1.2	-1.4	-3.1
53|43	-0.09	-0.26	-0.21	-0.9	-2.6	-2.1
53|43	-0.02	-0.43	-0.07	-0.2	-4.3	-0.7
53|43	0.21	-0.48	-0.26	2.1	-4.8	-2.6
53|43	0.04	-0.39	0.17	0.4	-3.9	1.7
53|43	-0.29	-0.26	0.56	-2.9	-2.6	5.6
53|43	-0.29	-0.34	0.21	-2.9	-3.4	2.1
53|43	-0.12	-0.51	0.02	-1.2	-5.1	0.2
53|43	0.07	-0.51	-0.29	0.7	-5.1	-2.9
53|43	0.09	-0.29	0	0.9	-2.9	0
53|43	0.04	-0.02	0.12	0.4	-0.2	1.2
53|43	-0.19	0.02	0.29	-1.9	0.2	2.9
53|43	-0.29	-0.09	0	-2.9	-0.9	0
53|43	-0.14	-0.17	-0.19	-1.4	-1.7	-1.9
53|43	0	-0.02	-0.09	0	-0.2	-0.9
53|43	0.07	0.31	0.34	0.7	3.1	3.4
53|43	0.07	0.56	0.53	0.7	5.6	5.3
53|43	0	0.43	0.46	0	4.3	4.6
53|43	-0.14	0.12	0.36	-1.4	1.2	3.6
53|43	-0.19	-0.14	0.19	-1.9	-1.4	1.9
53|43	-0.12	-0.19	0.12	-1.2	-1.9	1.2
53|43	-0.04	-0.04	0.17	-0.4	-0.4	1.7
53|43	-0.07	0.07	0.26	-0.7	0.7	2.6
53|43	-0.04	0.12	0.19	-0.4	1.2	1.9
53|43	-0.14	0.07	0.17	-1.4	0.7	1.7
53|43	-0.12	-0.04	0.07	-1.2	-0.4	0.7
53|43	0.02	-0.14	-0.09	0.2	-1.4	-0.9
53|43	0.02	-0.14	-0.12	0.2	-1.4	-1.2
53|44	0	-0.12	-0.07	0	-1.2	-0.7
53|44	-0.09	-0.14	-0.07	-0.9	-1.4	-0.7
53|44	-0.14	-0.14	-0.12	-1.4	-1.4	-1.2
53|44	-0.17	-0.19	0.04	-1.7	-1.9	0.4
53|44	-0.09	-0.14	-0.09	-0.9	-1.4	-0.9
53|44	-0.02	-0.14	-0.04	-0.2	-1.4	-0.4
53|44	-0.02	-0.12	-0.09	-0.2	-1.2	-0.9
53|44	-0.14	-0.07	0.07	-1.4	-0.7	0.7
53|44	-0.19	-0.09	0.07	-1.9	-0.9	0.7
53|44	0.04	-0.12	-0.17	0.4	-1.2	-1.7
53|44	0	0.02	0.04	0	0.2	0.4
53|44	-0.07	0.17	0.04	-0.7	1.7	0.4

53|44	0	0.17	-0.09	0	1.7	-0.9
53|44	-0.09	0.14	-0.07	-0.9	1.4	-0.7
53|44	-0.14	0.12	-0.07	-1.4	1.2	-0.7
53|44	-0.04	0.04	-0.17	-0.4	0.4	-1.7
53|44	-0.02	0.07	-0.12	-0.2	0.7	-1.2
53|44	-0.14	0.09	0	-1.4	0.9	0
53|44	-0.14	0.02	0	-1.4	0.2	0
53|44	0.04	-0.02	-0.12	0.4	-0.2	-1.2
53|44	-0.02	0.02	0.07	-0.2	0.2	0.7
53|44	-0.09	0.12	0.12	-0.9	1.2	1.2
53|44	-0.04	0.12	0.07	-0.4	1.2	0.7
53|44	0.02	0.04	-0.12	0.2	0.4	-1.2
53|44	-0.02	-0.09	0.09	-0.2	-0.9	0.9
53|44	0.12	-0.17	-0.29	1.2	-1.7	-2.9
53|44	0.09	-0.14	-0.39	0.9	-1.4	-3.9
53|44	-0.19	-0.17	-0.12	-1.9	-1.7	-1.2
53|44	-0.24	-0.31	-0.21	-2.4	-3.1	-2.1
53|44	-0.07	-0.51	-0.19	-0.7	-5.1	-1.9
53|44	-0.07	-0.56	0.02	-0.7	-5.6	0.2
53|44	0	-0.43	0.12	0	-4.3	1.2
53|44	-0.02	-0.31	0.19	-0.2	-3.1	1.9
53|44	-0.04	-0.26	0.21	-0.4	-2.6	2.1
53|44	-0.04	-0.36	0.09	-0.4	-3.6	0.9
53|44	-0.07	-0.36	0.09	-0.7	-3.6	0.9
53|44	-0.07	-0.31	0.12	-0.7	-3.1	1.2
53|44	-0.09	-0.07	0.17	-0.9	-0.7	1.7
53|44	-0.19	0.14	0.12	-1.9	1.4	1.2
53|44	-0.14	0.17	0.04	-1.4	1.7	0.4
53|44	0	0.12	0.04	0	1.2	0.4
53|44	0.02	0.14	0.24	0.2	1.4	2.4
53|44	0.04	0.21	0.19	0.4	2.1	1.9
53|44	-0.02	0.21	0.41	-0.2	2.1	4.1
53|44	-0.14	0.14	0.46	-1.4	1.4	4.6
53|44	-0.14	0.02	0.34	-1.4	0.2	3.4
53|44	-0.09	-0.07	0.26	-0.9	-0.7	2.6
53|44	-0.04	-0.02	0.26	-0.4	-0.2	2.6
53|44	0	0.04	0.26	0	0.4	2.6
53|44	-0.07	0.07	0.21	-0.7	0.7	2.1
53|44	-0.14	-0.02	0.04	-1.4	-0.2	0.4
53|44	-0.09	-0.19	-0.09	-0.9	-1.9	-0.9
53|44	-0.02	-0.21	-0.14	-0.2	-2.1	-1.4
53|44	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|44	0	0	0	0	0	0

53|44	-0.09	-0.02	-0.02	-0.9	-0.2	-0.2
53|44	-0.14	-0.09	0.09	-1.4	-0.9	0.9
53|44	-0.14	-0.21	-0.02	-1.4	-2.1	-0.2
53|44	-0.09	-0.21	-0.09	-0.9	-2.1	-0.9
53|44	-0.07	-0.19	-0.02	-0.7	-1.9	-0.2
53|44	-0.09	-0.09	-0.02	-0.9	-0.9	-0.2
53|44	-0.09	-0.07	0.04	-0.9	-0.7	0.4
53|44	-0.04	-0.04	0	-0.4	-0.4	0
53|44	-0.04	0.02	-0.07	-0.4	0.2	-0.7
53|44	-0.07	0.09	0.04	-0.7	0.9	0.4
53|44	-0.07	0.12	-0.14	-0.7	1.2	-1.4
53|44	-0.04	0.12	-0.24	-0.4	1.2	-2.4
53|44	-0.14	0.07	-0.12	-1.4	0.7	-1.2
53|44	-0.09	0.02	-0.12	-0.9	0.2	-1.2
53|44	0	0.04	-0.14	0	0.4	-1.4
53|44	-0.07	0.12	0	-0.7	1.2	0
53|44	-0.14	0.12	0.09	-1.4	1.2	0.9
53|44	-0.09	0.04	-0.07	-0.9	0.4	-0.7
53|44	-0.02	0.02	-0.24	-0.2	0.2	-2.4
53|44	-0.04	0.04	-0.14	-0.4	0.4	-1.4
53|44	-0.09	0.12	-0.07	-0.9	1.2	-0.7
53|44	0	0.09	-0.12	0	0.9	-1.2
53|44	0.04	0	-0.24	0.4	0	-2.4
53|44	-0.02	-0.07	-0.12	-0.2	-0.7	-1.2
53|44	0.02	-0.17	-0.09	0.2	-1.7	-0.9
53|44	0	-0.21	-0.14	0	-2.1	-1.4
53|44	-0.24	-0.07	-0.14	-2.4	-0.7	-1.4
53|44	-0.21	-0.39	-0.04	-2.1	-3.9	-0.4
53|44	0.02	-0.53	-0.21	0.2	-5.3	-2.1
53|44	0.12	-0.51	-0.14	1.2	-5.1	-1.4
53|44	0	-0.34	0.17	0	-3.4	1.7
53|44	-0.12	-0.19	0.31	-1.2	-1.9	3.1
53|44	-0.17	-0.26	0.17	-1.7	-2.6	1.7
53|44	-0.21	-0.39	0.12	-2.1	-3.9	1.2
53|44	-0.02	-0.41	0.02	-0.2	-4.1	0.2
53|44	0.09	-0.29	-0.02	0.9	-2.9	-0.2
53|44	0.02	-0.04	0.26	0.2	-0.4	2.6
53|44	-0.21	0.12	0.17	-2.1	1.2	1.7
53|44	-0.24	0.12	0.02	-2.4	1.2	0.2
53|44	-0.09	0.04	-0.04	-0.9	0.4	-0.4
53|44	0.04	0.07	0.02	0.4	0.7	0.2
53|44	0.19	0.26	0.21	1.9	2.6	2.1
53|44	0.04	0.43	0.53	0.4	4.3	5.3

53|44	-0.07	0.29	0.58	-0.7	2.9	5.8
53|44	-0.21	0.02	0.43	-2.1	0.2	4.3
53|44	-0.17	-0.21	0.24	-1.7	-2.1	2.4
53|44	-0.04	-0.21	0.09	-0.4	-2.1	0.9
53|44	-0.02	-0.04	0.14	-0.2	-0.4	1.4
53|44	-0.07	0.12	0.21	-0.7	1.2	2.1
53|44	-0.02	0.12	0.19	-0.2	1.2	1.9
53|44	-0.02	-0.02	-0.07	-0.2	-0.2	-0.7
53|44	-0.02	-0.17	-0.12	-0.2	-1.7	-1.2
53|44	0	-0.14	-0.19	0	-1.4	-1.9
53|44	-0.02	-0.09	-0.07	-0.2	-0.9	-0.7
53|44	-0.12	-0.09	0	-1.2	-0.9	0
53|44	-0.19	-0.21	-0.02	-1.9	-2.1	-0.2
53|44	-0.12	-0.24	-0.04	-1.2	-2.4	-0.4
53|44	-0.04	-0.17	-0.07	-0.4	-1.7	-0.7
53|44	-0.04	-0.07	0	-0.4	-0.7	0
53|44	-0.17	-0.02	0.04	-1.7	-0.2	0.4
53|44	-0.07	-0.07	-0.02	-0.7	-0.7	-0.2
53|44	-0.04	-0.07	-0.07	-0.4	-0.7	-0.7
53|44	-0.02	0	-0.02	-0.2	0	-0.2
53|44	-0.12	0.14	0.04	-1.2	1.4	0.4
53|44	-0.12	0.19	0.07	-1.2	1.9	0.7
53|44	-0.09	0.12	0	-0.9	1.2	0
53|44	-0.02	0	-0.14	-0.2	0	-1.4
53|44	-0.04	0	-0.04	-0.4	0	-0.4
53|44	-0.04	0.07	-0.07	-0.4	0.7	-0.7
53|44	-0.12	0.14	0	-1.2	1.4	0
53|44	-0.17	0.09	0.02	-1.7	0.9	0.2
53|44	-0.14	-0.02	-0.04	-1.4	-0.2	-0.4
53|44	0.02	-0.07	-0.19	0.2	-0.7	-1.9
53|44	0	0.02	-0.19	0	0.2	-1.9
53|44	-0.12	0.21	0.12	-1.2	2.1	1.2
53|44	-0.04	0.14	-0.09	-0.4	1.4	-0.9
53|44	0.14	-0.04	-0.26	1.4	-0.4	-2.6
53|44	0.02	-0.07	-0.21	0.2	-0.7	-2.1
53|44	-0.12	-0.07	-0.17	-1.2	-0.7	-1.7
53|44	-0.09	-0.09	-0.29	-0.9	-0.9	-2.9
53|44	-0.07	-0.21	-0.14	-0.7	-2.1	-1.4
53|44	-0.12	-0.36	0.02	-1.2	-3.6	0.2
53|44	0.17	-0.53	-0.19	1.7	-5.3	-1.9
53|44	0.04	-0.46	0.12	0.4	-4.6	1.2
53|44	-0.21	-0.29	0.51	-2.1	-2.9	5.1
53|44	-0.19	-0.31	0.24	-1.9	-3.1	2.4

53|44	-0.07	-0.43	0.07	-0.7	-4.3	0.7
53|44	-0.02	-0.43	-0.04	-0.2	-4.3	-0.4
53|44	0.02	-0.34	0.07	0.2	-3.4	0.7
53|44	0	-0.12	0.14	0	-1.2	1.4
53|44	-0.17	0	0.31	-1.7	0	3.1
53|44	-0.24	-0.07	0.14	-2.4	-0.7	1.4
53|44	-0.14	-0.07	-0.04	-1.4	-0.7	-0.4
53|44	-0.07	0	0	-0.7	0	0
53|44	0.04	0.24	0.21	0.4	2.4	2.1
53|44	0.07	0.43	0.51	0.7	4.3	5.1
53|44	0.02	0.39	0.51	0.2	3.9	5.1
53|44	-0.04	0.12	0.43	-0.4	1.2	4.3
53|44	-0.19	-0.09	0.29	-1.9	-0.9	2.9
53|44	-0.21	-0.19	0.26	-2.1	-1.9	2.6
53|44	-0.04	-0.09	0.14	-0.4	-0.9	1.4
53|44	0	0.02	0.24	0	0.2	2.4
53|44	-0.04	0.14	0.31	-0.4	1.4	3.1
53|44	-0.07	0.09	0.24	-0.7	0.9	2.4
53|44	-0.09	-0.02	0.07	-0.9	-0.2	0.7
53|44	-0.04	-0.12	0	-0.4	-1.2	0
53|44	0	-0.17	-0.02	0	-1.7	-0.2
53|44	0	-0.19	-0.07	0	-1.9	-0.7
53|44	-0.04	-0.17	-0.04	-0.4	-1.7	-0.4
53|44	-0.17	-0.17	0.04	-1.7	-1.7	0.4
53|44	-0.12	-0.17	0.02	-1.2	-1.7	0.2
53|44	-0.07	-0.19	-0.09	-0.7	-1.9	-0.9
53|44	-0.07	-0.14	0	-0.7	-1.4	0
53|44	-0.07	-0.12	0	-0.7	-1.2	0
53|44	-0.12	0.04	0.34	-1.2	0.4	3.4
53|44	-0.19	-0.04	0.26	-1.9	-0.4	2.6
53|44	-0.09	-0.07	0.26	-0.9	-0.7	2.6
53|44	-0.04	-0.02	0.26	-0.4	-0.2	2.6
53|44	-0.07	0.04	0.29	-0.7	0.4	2.9
53|44	-0.07	0	0.31	-0.7	0	3.1
53|44	-0.07	-0.04	0.04	-0.7	-0.4	0.4
53|44	-0.04	-0.09	-0.07	-0.4	-0.9	-0.7
53|44	-0.04	-0.07	-0.04	-0.4	-0.7	-0.4
53|44	-0.02	-0.04	-0.12	-0.2	-0.4	-1.2
53|44	0.04	-0.04	-0.17	0.4	-0.4	-1.7
53|44	-0.09	-0.02	0.07	-0.9	-0.2	0.7
53|44	-0.17	-0.14	0.14	-1.7	-1.4	1.4
53|44	-0.12	-0.21	-0.04	-1.2	-2.1	-0.4
53|44	-0.12	-0.24	0.04	-1.2	-2.4	0.4

53|44	-0.12	-0.21	0.12	-1.2	-2.1	1.2
53|44	-0.07	-0.14	0	-0.7	-1.4	0
53|44	-0.07	-0.02	0.02	-0.7	-0.2	0.2
53|44	-0.04	0.04	0	-0.4	0.4	0
53|44	-0.04	0.12	-0.04	-0.4	1.2	-0.4
53|44	-0.04	0.12	0	-0.4	1.2	0
53|44	-0.07	0.14	-0.02	-0.7	1.4	-0.2
53|44	-0.09	0	-0.02	-0.9	0	-0.2
53|44	-0.09	0.04	0	-0.9	0.4	0
53|44	-0.07	0.04	-0.07	-0.7	0.4	-0.7
53|44	-0.14	0.02	0.09	-1.4	0.2	0.9
53|44	-0.07	0.09	0.02	-0.7	0.9	0.2
53|44	-0.07	0.09	-0.04	-0.7	0.9	-0.4
53|44	-0.04	0.09	-0.07	-0.4	0.9	-0.7
53|44	0.02	0.07	-0.04	0.2	0.7	-0.4
53|44	0	0.12	-0.07	0	1.2	-0.7
53|44	-0.14	0.14	0.12	-1.4	1.4	1.2
53|44	-0.07	0.04	-0.07	-0.7	0.4	-0.7
53|44	0.09	-0.09	-0.19	0.9	-0.9	-1.9
53|44	0.09	-0.12	0	0.9	-1.2	0
53|44	0.04	-0.09	-0.19	0.4	-0.9	-1.9
53|44	-0.07	-0.14	-0.09	-0.7	-1.4	-0.9
53|44	-0.21	-0.26	0	-2.1	-2.6	0
53|44	-0.12	-0.43	-0.12	-1.2	-4.3	-1.2
53|44	0.12	-0.58	-0.04	1.2	-5.8	-0.4
53|44	0.12	-0.46	0.12	1.2	-4.6	1.2
53|44	-0.02	-0.26	0.31	-0.2	-2.6	3.1
53|44	-0.12	-0.19	0.26	-1.2	-1.9	2.6
53|44	-0.21	-0.31	0.19	-2.1	-3.1	1.9
53|44	-0.12	-0.51	0.07	-1.2	-5.1	0.7
53|44	0.07	-0.46	-0.04	0.7	-4.6	-0.4
53|44	0.09	-0.21	0.04	0.9	-2.1	0.4
53|44	-0.12	0.04	0.31	-1.2	0.4	3.1
53|44	-0.21	0.12	0.21	-2.1	1.2	2.1
53|44	-0.17	0.02	0.04	-1.7	0.2	0.4
53|44	0	0	-0.04	0	0	-0.4
53|44	0.09	0.19	0.17	0.9	1.9	1.7
53|44	0.12	0.43	0.31	1.2	4.3	3.1
53|44	-0.02	0.48	0.46	-0.2	4.8	4.6
53|44	-0.19	0.19	0.41	-1.9	1.9	4.1
53|44	-0.21	-0.14	0.19	-2.1	-1.4	1.9
53|44	-0.09	-0.31	0.17	-0.9	-3.1	1.7
53|44	-0.02	-0.21	0.24	-0.2	-2.1	2.4

53|44	-0.04	0.02	0.39	-0.4	0.2	3.9
53|44	-0.14	0.14	0.36	-1.4	1.4	3.6
53|44	-0.04	0.04	0.09	-0.4	0.4	0.9
53|44	-0.02	-0.07	-0.04	-0.2	-0.7	-0.4
53|44	0	-0.12	-0.14	0	-1.2	-1.4
53|44	0	0	-0.17	0	0	-1.7
53|44	-0.09	-0.02	-0.07	-0.9	-0.2	-0.7
53|44	-0.12	-0.14	0	-1.2	-1.4	0
53|44	-0.09	-0.26	-0.07	-0.9	-2.6	-0.7
53|44	-0.09	-0.24	-0.04	-0.9	-2.4	-0.4
53|44	-0.12	-0.12	-0.02	-1.2	-1.2	-0.2
53|44	-0.09	-0.02	-0.02	-0.9	-0.2	-0.2
53|44	-0.04	-0.04	0	-0.4	-0.4	0
53|44	-0.07	-0.07	-0.02	-0.7	-0.7	-0.2
53|44	-0.04	-0.07	-0.07	-0.4	-0.7	-0.7
53|44	-0.07	0.02	0.02	-0.7	0.2	0.2
53|44	-0.17	0.14	0.04	-1.7	1.4	0.4
53|44	-0.12	0.09	-0.02	-1.2	0.9	-0.2
53|44	0.02	0.02	-0.19	0.2	0.2	-1.9
53|44	0	0.02	-0.07	0	0.2	-0.7
53|44	-0.09	0.12	-0.04	-0.9	1.2	-0.4
53|44	-0.09	0.14	0.04	-0.9	1.4	0.4
53|44	-0.21	0.17	0.17	-2.1	1.7	1.7
53|44	-0.17	0	0	-1.7	0	0
53|44	0	-0.07	-0.19	0	-0.7	-1.9
53|44	0.09	0.07	-0.21	0.9	0.7	-2.1
53|44	-0.02	0.24	0.14	-0.2	2.4	1.4
53|44	-0.07	0.24	0.04	-0.7	2.4	0.4
53|44	0.04	0.04	-0.21	0.4	0.4	-2.1
53|44	0	-0.09	-0.29	0	-0.9	-2.9
53|44	-0.07	-0.19	-0.14	-0.7	-1.9	-1.4
53|44	-0.04	-0.17	-0.19	-0.4	-1.7	-1.9
53|44	-0.09	-0.17	-0.21	-0.9	-1.7	-2.1
53|44	-0.17	-0.26	0.04	-1.7	-2.6	0.4
53|44	0.12	-0.46	-0.09	1.2	-4.6	-0.9
53|44	0.14	-0.46	-0.02	1.4	-4.6	-0.2
53|44	-0.12	-0.31	0.36	-1.2	-3.1	3.6
53|44	-0.21	-0.26	0.21	-2.1	-2.6	2.1
53|44	-0.17	-0.39	0	-1.7	-3.9	0
53|44	-0.09	-0.48	-0.14	-0.9	-4.8	-1.4
53|44	0.02	-0.48	-0.02	0.2	-4.8	-0.2
53|44	0.12	-0.24	0.07	1.2	-2.4	0.7
53|44	-0.07	-0.04	0.39	-0.7	-0.4	3.9

53|44	-0.24	0.02	0.07	-2.4	0.2	0.7
53|44	-0.17	-0.07	0.04	-1.7	-0.7	0.4
53|44	-0.04	-0.04	-0.02	-0.4	-0.4	-0.2
53|44	0.02	0.17	0.12	0.2	1.7	1.2
53|44	0.09	0.43	0.31	0.9	4.3	3.1
53|44	0.04	0.48	0.46	0.4	4.8	4.6
53|44	-0.12	0.26	0.43	-1.2	2.6	4.3
53|44	-0.19	-0.07	0.19	-1.9	-0.7	1.9
53|44	-0.17	-0.26	0.07	-1.7	-2.6	0.7
53|44	-0.09	-0.19	0.12	-0.9	-1.9	1.2
53|44	-0.04	-0.02	0.26	-0.4	-0.2	2.6
53|44	-0.07	0.12	0.36	-0.7	1.2	3.6
53|44	-0.14	0.09	0.26	-1.4	0.9	2.6
53|44	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|44	-0.04	-0.14	-0.07	-0.4	-1.4	-0.7
53|44	-0.12	-0.19	-0.02	-1.2	-1.9	-0.2
53|44	-0.14	-0.19	0	-1.4	-1.9	0
53|44	-0.09	-0.17	-0.02	-0.9	-1.7	-0.2
53|44	-0.09	-0.14	0.04	-0.9	-1.4	0.4
53|44	-0.12	-0.14	0.02	-1.2	-1.4	0.2
53|44	-0.07	-0.12	-0.04	-0.7	-1.2	-0.4
53|44	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|44	-0.07	0.02	0.07	-0.7	0.2	0.7
53|44	-0.04	0.09	0	-0.4	0.9	0
53|44	-0.07	0.17	-0.04	-0.7	1.7	-0.4
53|44	-0.09	0.07	0	-0.9	0.7	0
53|44	-0.09	0.04	-0.07	-0.9	0.4	-0.7
53|44	0	0.04	-0.12	0	0.4	-1.2
53|44	-0.07	0.09	0.07	-0.7	0.9	0.7
53|44	-0.14	0.02	0.04	-1.4	0.2	0.4
53|44	-0.14	0.02	-0.04	-1.4	0.2	-0.4
53|44	-0.07	-0.02	-0.02	-0.7	-0.2	-0.2
53|44	-0.04	0	-0.12	-0.4	0	-1.2
53|44	0.02	0.04	-0.09	0.2	0.4	-0.9
53|44	-0.04	0.17	0	-0.4	1.7	0
53|44	-0.14	0.14	0.12	-1.4	1.4	1.2
53|44	0	0	-0.21	0	0	-2.1
53|44	0.14	-0.09	-0.26	1.4	-0.9	-2.6
53|44	0	-0.07	0	0	-0.7	0
53|44	-0.14	-0.02	0	-1.4	-0.2	0
53|44	-0.09	-0.14	-0.31	-0.9	-1.4	-3.1
53|44	-0.12	-0.29	-0.21	-1.2	-2.9	-2.1
53|44	0.02	-0.43	-0.17	0.2	-4.3	-1.7

53|44	0.26	-0.41	-0.24	2.6	-4.1	-2.4
53|44	-0.04	-0.24	0.31	-0.4	-2.4	3.1
53|44	-0.31	-0.21	0.46	-3.1	-2.1	4.6
53|44	-0.24	-0.39	0.07	-2.4	-3.9	0.7
53|44	-0.09	-0.58	-0.04	-0.9	-5.8	-0.4
53|44	0.07	-0.53	-0.07	0.7	-5.3	-0.7
53|44	0.12	-0.24	0.17	1.2	-2.4	1.7
53|44	0.04	0.02	0.24	0.4	0.2	2.4
53|44	-0.26	0.07	0.24	-2.6	0.7	2.4
53|44	-0.24	-0.07	0.04	-2.4	-0.7	0.4
53|44	-0.09	-0.17	-0.09	-0.9	-1.7	-0.9
53|44	0.02	0.04	0.04	0.2	0.4	0.4
53|44	0.07	0.36	0.34	0.7	3.6	3.4
53|45	0.09	0.48	0.51	0.9	4.8	5.1
53|45	-0.07	0.34	0.43	-0.7	3.4	4.3
53|45	-0.21	0	0.41	-2.1	0	4.1
53|45	-0.17	-0.21	0.12	-1.7	-2.1	1.2
53|45	-0.14	-0.21	0.24	-1.4	-2.1	2.4
53|45	-0.04	-0.02	0.17	-0.4	-0.2	1.7
53|45	0	0.14	0.29	0	1.4	2.9
53|45	-0.07	0.14	0.26	-0.7	1.4	2.6
53|45	-0.14	0.09	0.14	-1.4	0.9	1.4
53|45	-0.04	-0.02	-0.12	-0.4	-0.2	-1.2
53|45	0.02	-0.04	-0.21	0.2	-0.4	-2.1
53|45	0	-0.07	-0.04	0	-0.7	-0.4
53|45	-0.02	-0.12	-0.07	-0.2	-1.2	-0.7
53|45	-0.07	-0.12	-0.04	-0.7	-1.2	-0.4
53|45	-0.21	0	0.07	-2.1	0	0.7
53|45	-0.14	-0.21	0.02	-1.4	-2.1	0.2
53|45	-0.02	-0.21	-0.12	-0.2	-2.1	-1.2
53|45	-0.04	-0.17	-0.04	-0.4	-1.7	-0.4
53|45	-0.12	-0.09	0.04	-1.2	-0.9	0.4
53|45	-0.14	-0.12	-0.02	-1.4	-1.2	-0.2
53|45	-0.12	-0.09	0.07	-1.2	-0.9	0.7
53|45	0.07	-0.04	-0.09	0.7	-0.4	-0.9
53|45	0.02	0.09	-0.04	0.2	0.9	-0.4
53|45	-0.04	0.19	0.02	-0.4	1.9	0.2
53|45	-0.09	0.19	-0.04	-0.9	1.9	-0.4
53|45	-0.12	0.12	0	-1.2	1.2	0
53|45	-0.09	0.02	-0.12	-0.9	0.2	-1.2
53|45	0	0	-0.26	0	0	-2.6
53|45	-0.07	0.04	-0.04	-0.7	0.4	-0.4
53|45	-0.19	0.09	0.07	-1.9	0.9	0.7

53|45	-0.17	-0.02	-0.07	-1.7	-0.2	-0.7
53|45	-0.02	-0.07	-0.17	-0.2	-0.7	-1.7
53|45	0.07	0	-0.09	0.7	0	-0.9
53|45	-0.02	0.14	0.07	-0.2	1.4	0.7
53|45	-0.07	0.21	-0.04	-0.7	2.1	-0.4
53|45	-0.02	0.07	-0.17	-0.2	0.7	-1.7
53|45	-0.02	-0.09	-0.19	-0.2	-0.9	-1.9
53|45	0.07	-0.19	-0.21	0.7	-1.9	-2.1
53|45	0.14	-0.17	-0.12	1.4	-1.7	-1.2
53|45	-0.07	-0.09	0.07	-0.7	-0.9	0.7
53|45	-0.19	-0.17	0.07	-1.9	-1.7	0.7
53|45	-0.12	-0.41	-0.24	-1.2	-4.1	-2.4
53|45	-0.07	-0.56	-0.21	-0.7	-5.6	-2.1
53|45	-0.02	-0.48	-0.02	-0.2	-4.8	-0.2
53|45	-0.04	-0.31	0.07	-0.4	-3.1	0.7
53|45	-0.12	-0.26	0.29	-1.2	-2.6	2.9
53|45	-0.07	-0.31	0.09	-0.7	-3.1	0.9
53|45	-0.02	-0.46	0.02	-0.2	-4.6	0.2
53|45	-0.09	-0.43	0.12	-0.9	-4.3	1.2
53|45	-0.07	-0.21	0.17	-0.7	-2.1	1.7
53|45	-0.12	0	0.12	-1.2	0	1.2
53|45	-0.17	0.12	0.07	-1.7	1.2	0.7
53|45	-0.12	0.12	0	-1.2	1.2	0
53|45	0.04	0.12	-0.02	0.4	1.2	-0.2
53|45	0.04	0.21	0.21	0.4	2.1	2.1
53|45	0	0.29	0.34	0	2.9	3.4
53|45	-0.09	0.24	0.43	-0.9	2.4	4.3
53|45	-0.19	0.02	0.31	-1.9	0.2	3.1
53|45	-0.19	-0.09	0.26	-1.9	-0.9	2.6
53|45	-0.04	-0.09	0.24	-0.4	-0.9	2.4
53|45	-0.02	0.07	0.29	-0.2	0.7	2.9
53|45	-0.02	0.17	0.26	-0.2	1.7	2.6
53|45	-0.09	0.12	0.31	-0.9	1.2	3.1
53|45	-0.12	-0.02	0.09	-1.2	-0.2	0.9
53|45	-0.07	-0.14	-0.07	-0.7	-1.4	-0.7
53|45	-0.07	-0.12	-0.09	-0.7	-1.2	-0.9
53|45	-0.02	-0.07	-0.14	-0.2	-0.7	-1.4
53|45	0.02	0.04	0	0.2	0.4	0
53|45	-0.04	-0.02	0	-0.4	-0.2	0
53|45	-0.12	-0.12	0.02	-1.2	-1.2	0.2
53|45	-0.07	-0.21	-0.07	-0.7	-2.1	-0.7
53|45	-0.14	-0.21	-0.02	-1.4	-2.1	-0.2
53|45	-0.12	-0.19	0.02	-1.2	-1.9	0.2

53|45	-0.07	-0.17	0	-0.7	-1.7	0
53|45	-0.07	-0.12	0	-0.7	-1.2	0
53|45	-0.07	0	0.02	-0.7	0	0.2
53|45	-0.02	0.07	0	-0.2	0.7	0
53|45	0	0.14	-0.02	0	1.4	-0.2
53|45	-0.12	0.17	-0.04	-1.2	1.7	-0.4
53|45	-0.14	0.09	-0.04	-1.4	0.9	-0.4
53|45	-0.09	0.02	-0.07	-0.9	0.2	-0.7
53|45	0	0.04	-0.12	0	0.4	-1.2
53|45	-0.04	0.12	0.07	-0.4	1.2	0.7
53|45	-0.12	0.14	0.07	-1.2	1.4	0.7
53|45	-0.12	0.02	-0.04	-1.2	0.2	-0.4
53|45	-0.12	0.02	0	-1.2	0.2	0
53|45	-0.09	0	-0.07	-0.9	0	-0.7
53|45	0.02	0.02	-0.14	0.2	0.2	-1.4
53|45	-0.02	0.12	0.02	-0.2	1.2	0.2
53|45	-0.04	0.12	-0.02	-0.4	1.2	-0.2
53|45	0.04	0.02	-0.14	0.4	0.2	-1.4
53|45	0.07	-0.09	-0.19	0.7	-0.9	-1.9
53|45	0.02	-0.17	-0.12	0.2	-1.7	-1.2
53|45	-0.02	-0.24	-0.02	-0.2	-2.4	-0.2
53|45	-0.24	-0.26	-0.02	-2.4	-2.6	-0.2
53|45	-0.24	-0.36	-0.02	-2.4	-3.6	-0.2
53|45	0.04	-0.56	-0.19	0.4	-5.6	-1.9
53|45	0.17	-0.51	-0.19	1.7	-5.1	-1.9
53|45	0	-0.34	0.21	0	-3.4	2.1
53|45	-0.07	-0.21	0.24	-0.7	-2.1	2.4
53|45	-0.17	-0.26	0.24	-1.7	-2.6	2.4
53|45	-0.19	-0.36	0.17	-1.9	-3.6	1.7
53|45	0	-0.46	0	0	-4.6	0
53|45	0.12	-0.29	0	1.2	-2.9	0
53|45	0.02	0.02	0.41	0.2	0.2	4.1
53|45	-0.14	0.19	0.19	-1.4	1.9	1.9
53|45	-0.14	0.14	0.04	-1.4	1.4	0.4
53|45	-0.12	0.04	-0.02	-1.2	0.4	-0.2
53|45	0.02	0.09	-0.04	0.2	0.9	-0.4
53|45	0.17	0.26	0.14	1.7	2.6	1.4
53|45	0.04	0.46	0.53	0.4	4.6	5.3
53|45	-0.09	0.36	0.48	-0.9	3.6	4.8
53|45	-0.12	0.07	0.39	-1.2	0.7	3.9
53|45	-0.14	-0.17	0.29	-1.4	-1.7	2.9
53|45	-0.07	-0.24	0.21	-0.7	-2.4	2.1
53|45	-0.04	-0.02	0.24	-0.4	-0.2	2.4

53|45	-0.04	0.12	0.26	-0.4	1.2	2.6
53|45	-0.07	0.14	0.21	-0.7	1.4	2.1
53|45	-0.07	0.02	0.04	-0.7	0.2	0.4
53|45	0.02	-0.07	-0.14	0.2	-0.7	-1.4
53|45	0.02	-0.07	-0.21	0.2	-0.7	-2.1
53|45	-0.07	-0.04	0.02	-0.7	-0.4	0.2
53|45	-0.14	-0.09	-0.04	-1.4	-0.9	-0.4
53|45	-0.14	-0.24	-0.07	-1.4	-2.4	-0.7
53|45	-0.07	-0.26	-0.12	-0.7	-2.6	-1.2
53|45	-0.07	-0.19	0	-0.7	-1.9	0
53|45	-0.09	-0.07	0.02	-0.9	-0.7	0.2
53|45	-0.02	-0.02	0.02	-0.2	-0.2	0.2
53|45	-0.09	-0.02	0	-0.9	-0.2	0
53|45	-0.07	-0.12	-0.02	-0.7	-1.2	-0.2
53|45	-0.07	-0.07	-0.04	-0.7	-0.7	-0.4
53|45	-0.09	0.07	-0.07	-0.9	0.7	-0.7
53|45	-0.17	0.17	0.04	-1.7	1.7	0.4
53|45	-0.09	0.12	-0.04	-0.9	1.2	-0.4
53|45	0.04	0.04	-0.19	0.4	0.4	-1.9
53|45	-0.04	0.07	0.12	-0.4	0.7	1.2
53|45	-0.12	0.12	0.04	-1.2	1.2	0.4
53|45	-0.17	0.12	0	-1.7	1.2	0
53|45	-0.12	0.04	-0.09	-1.2	0.4	-0.9
53|45	-0.07	-0.02	-0.14	-0.7	-0.2	-1.4
53|45	0.04	0	-0.19	0.4	0	-1.9
53|45	-0.04	0.17	0	-0.4	1.7	0
53|45	-0.09	0.24	0.14	-0.9	2.4	1.4
53|45	0	0.09	-0.09	0	0.9	-0.9
53|45	0.09	-0.12	-0.24	0.9	-1.2	-2.4
53|45	-0.02	-0.17	-0.17	-0.2	-1.7	-1.7
53|45	-0.14	-0.14	-0.17	-1.4	-1.4	-1.7
53|45	-0.17	-0.14	-0.17	-1.7	-1.4	-1.7
53|45	-0.12	-0.31	0.12	-1.2	-3.1	1.2
53|45	0.17	-0.46	-0.04	1.7	-4.6	-0.4
53|45	0.17	-0.46	-0.04	1.7	-4.6	-0.4
53|45	-0.12	-0.31	0.21	-1.2	-3.1	2.1
53|45	-0.26	-0.26	0.19	-2.6	-2.6	1.9
53|45	-0.24	-0.36	-0.07	-2.4	-3.6	-0.7
53|45	-0.09	-0.51	-0.02	-0.9	-5.1	-0.2
53|45	0.09	-0.48	-0.09	0.9	-4.8	-0.9
53|45	0.12	-0.24	0.14	1.2	-2.4	1.4
53|45	-0.07	0	0.31	-0.7	0	3.1
53|45	-0.24	0	0.31	-2.4	0	3.1

53|45	-0.19	-0.14	0.14	-1.9	-1.4	1.4
53|45	-0.07	-0.14	-0.04	-0.7	-1.4	-0.4
53|45	0.07	0.07	0.04	0.7	0.7	0.4
53|45	0.02	0.43	0.34	0.2	4.3	3.4
53|45	-0.02	0.53	0.43	-0.2	5.3	4.3
53|45	-0.04	0.31	0.41	-0.4	3.1	4.1
53|45	-0.04	-0.02	0.24	-0.4	-0.2	2.4
53|45	-0.19	-0.17	0.17	-1.9	-1.7	1.7
53|45	-0.12	-0.19	0.21	-1.2	-1.9	2.1
53|45	-0.04	0	0.24	-0.4	0	2.4
53|45	-0.04	0.09	0.31	-0.4	0.9	3.1
53|45	-0.07	0.07	0.24	-0.7	0.7	2.4
53|45	-0.07	-0.02	0.07	-0.7	-0.2	0.7
53|45	-0.04	-0.07	-0.09	-0.4	-0.7	-0.9
53|45	-0.02	-0.09	-0.17	-0.2	-0.9	-1.7
53|45	-0.02	-0.12	-0.14	-0.2	-1.2	-1.4
53|45	0	-0.17	-0.14	0	-1.7	-1.4
53|45	-0.09	-0.17	0	-0.9	-1.7	0
53|45	-0.19	-0.14	-0.02	-1.9	-1.4	-0.2
53|45	-0.09	-0.14	-0.07	-0.9	-1.4	-0.7
53|45	-0.09	-0.09	-0.02	-0.9	-0.9	-0.2
53|45	-0.04	-0.09	-0.04	-0.4	-0.9	-0.4
53|45	-0.07	-0.07	-0.04	-0.7	-0.7	-0.4
53|45	-0.14	-0.07	0	-1.4	-0.7	0
53|45	-0.04	-0.07	-0.19	-0.4	-0.7	-1.9
53|45	0	-0.02	-0.21	0	-0.2	-2.1
53|45	-0.07	0.04	-0.07	-0.7	0.4	-0.7
53|45	-0.09	0.09	-0.04	-0.9	0.9	-0.4
53|45	-0.04	0.09	-0.12	-0.4	0.9	-1.2
53|45	-0.12	0.09	-0.07	-1.2	0.9	-0.7
53|45	-0.12	0.07	-0.12	-1.2	0.7	-1.2
53|45	-0.02	0.04	-0.21	-0.2	0.4	-2.1
53|45	-0.07	0.07	-0.09	-0.7	0.7	-0.9
53|45	-0.17	0.07	0	-1.7	0.7	0
53|45	-0.07	0	-0.04	-0.7	0	-0.4
53|45	0	0.04	-0.14	0	0.4	-1.4
53|45	-0.04	0.09	-0.04	-0.4	0.9	-0.4
53|45	-0.02	0.14	-0.07	-0.2	1.4	-0.7
53|45	0.04	0.07	-0.21	0.4	0.7	-2.1
53|45	-0.07	0	-0.17	-0.7	0	-1.7
53|45	0	-0.17	-0.36	0	-1.7	-3.6
53|45	0.04	-0.21	-0.36	0.4	-2.1	-3.6
53|45	-0.17	-0.24	0	-1.7	-2.4	0

53|45	-0.17	-0.34	-0.04	-1.7	-3.4	-0.4
53|45	-0.02	-0.41	0	-0.2	-4.1	0
53|45	-0.04	-0.43	0.12	-0.4	-4.3	1.2
53|45	-0.02	-0.43	0.12	-0.2	-4.3	1.2
53|45	-0.04	-0.34	0.09	-0.4	-3.4	0.9
53|45	-0.07	-0.29	0.07	-0.7	-2.9	0.7
53|45	-0.04	-0.36	0	-0.4	-3.6	0
53|45	-0.02	-0.36	0.02	-0.2	-3.6	0.2
53|45	-0.09	-0.26	0.09	-0.9	-2.6	0.9
53|45	-0.14	-0.12	0.14	-1.4	-1.2	1.4
53|45	-0.17	0	0.14	-1.7	0	1.4
53|45	-0.12	0.02	0.14	-1.2	0.2	1.4
53|45	0	0.07	0.12	0	0.7	1.2
53|45	0	0.12	0.34	0	1.2	3.4
53|45	0	0.21	0.48	0	2.1	4.8
53|45	-0.09	0.24	0.61	-0.9	2.4	6.1
53|45	-0.07	0.14	0.48	-0.7	1.4	4.8
53|45	-0.12	0.02	0.39	-1.2	0.2	3.9
53|45	-0.04	-0.02	0.24	-0.4	-0.2	2.4
53|45	-0.04	0.04	0.19	-0.4	0.4	1.9
53|45	-0.09	0.07	0.21	-0.9	0.7	2.1
53|45	-0.09	0	0.29	-0.9	0	2.9
53|45	-0.12	-0.12	0.21	-1.2	-1.2	2.1
53|45	-0.04	-0.19	0	-0.4	-1.9	0
53|45	-0.02	-0.19	0	-0.2	-1.9	0
53|45	-0.07	-0.09	0.04	-0.7	-0.9	0.4
53|45	-0.07	-0.04	0.07	-0.7	-0.4	0.7
53|45	0.02	-0.07	-0.04	0.2	-0.7	-0.4
53|45	-0.09	-0.09	0.07	-0.9	-0.9	0.7
53|45	-0.12	-0.14	0.09	-1.2	-1.4	0.9
53|45	-0.07	-0.14	-0.02	-0.7	-1.4	-0.2
53|45	-0.12	-0.17	-0.04	-1.2	-1.7	-0.4
53|45	-0.07	-0.12	-0.09	-0.7	-1.2	-0.9
53|45	-0.12	-0.09	0	-1.2	-0.9	0
53|45	-0.07	-0.07	0	-0.7	-0.7	0
53|45	-0.02	0.02	0	-0.2	0.2	0
53|45	-0.02	0.09	0	-0.2	0.9	0
53|45	-0.17	0.07	0.14	-1.7	0.7	1.4
53|45	-0.14	0.04	-0.02	-1.4	0.4	-0.2
53|45	-0.07	0	-0.17	-0.7	0	-1.7
53|45	-0.04	-0.02	-0.17	-0.4	-0.2	-1.7
53|45	-0.04	0.07	-0.07	-0.4	0.7	-0.7
53|45	-0.04	0.07	-0.07	-0.4	0.7	-0.7

53|45	-0.07	0.26	-0.07	-0.7	2.6	-0.7
53|45	-0.17	0.09	0	-1.7	0.9	0
53|45	-0.12	0.02	-0.07	-1.2	0.2	-0.7
53|45	0.02	0.02	-0.14	0.2	0.2	-1.4
53|45	-0.02	0.07	0	-0.2	0.7	0
53|45	-0.02	0.09	0	-0.2	0.9	0
53|45	0.04	0	-0.14	0.4	0	-1.4
53|45	0.09	-0.09	-0.24	0.9	-0.9	-2.4
53|45	-0.02	-0.17	-0.17	-0.2	-1.7	-1.7
53|45	-0.04	-0.19	-0.24	-0.4	-1.9	-2.4
53|45	-0.19	-0.24	-0.02	-1.9	-2.4	-0.2
53|45	-0.19	-0.34	-0.04	-1.9	-3.4	-0.4
53|45	-0.02	-0.46	-0.17	-0.2	-4.6	-1.7
53|45	0.14	-0.53	-0.04	1.4	-5.3	-0.4
53|45	-0.09	-0.07	0.26	-0.9	-0.7	2.6
53|45	-0.12	-0.19	0.21	-1.2	-1.9	2.1
53|45	-0.17	-0.19	0.31	-1.7	-1.9	3.1
53|45	-0.19	-0.09	0.24	-1.9	-0.9	2.4
53|45	-0.07	0	0.14	-0.7	0	1.4
53|45	0	0.07	0.14	0	0.7	1.4
53|45	0	0.14	0.07	0	1.4	0.7
53|45	0	0.12	0.02	0	1.2	0.2
53|45	-0.04	0	-0.14	-0.4	0	-1.4
53|45	-0.12	-0.07	-0.07	-1.2	-0.7	-0.7
53|45	-0.07	-0.19	-0.14	-0.7	-1.9	-1.4
53|45	-0.09	-0.21	-0.07	-0.9	-2.1	-0.7
53|45	-0.09	-0.17	0.02	-0.9	-1.7	0.2
53|45	-0.14	-0.07	-0.02	-1.4	-0.7	-0.2
53|45	-0.09	-0.14	-0.04	-0.9	-1.4	-0.4
53|45	-0.04	-0.17	-0.17	-0.4	-1.7	-1.7
53|45	-0.04	-0.14	-0.12	-0.4	-1.4	-1.2
53|45	-0.09	0.04	-0.02	-0.9	0.4	-0.2
53|45	-0.04	0.14	-0.09	-0.4	1.4	-0.9
53|45	-0.04	0.14	0.04	-0.4	1.4	0.4
53|45	-0.14	0.09	0.04	-1.4	0.9	0.4
53|45	-0.07	0.02	-0.09	-0.7	0.2	-0.9
53|45	0.07	0.02	-0.17	0.7	0.2	-1.7
53|45	-0.04	0.12	0.12	-0.4	1.2	1.2
53|45	-0.24	0.14	0.14	-2.4	1.4	1.4
53|45	-0.12	0	-0.07	-1.2	0	-0.7
53|45	-0.12	-0.09	-0.21	-1.2	-0.9	-2.1
53|45	-0.12	-0.04	0.02	-1.2	-0.4	0.2
53|45	-0.07	0.07	0	-0.7	0.7	0

53|45	0.04	0.19	-0.14	0.4	1.9	-1.4
53|45	-0.17	0.26	0.19	-1.7	2.6	1.9
53|45	-0.04	0.12	-0.09	-0.4	1.2	-0.9
53|45	0.31	-0.07	-0.29	3.1	-0.7	-2.9
53|45	0.12	-0.02	-0.09	1.2	-0.2	-0.9
53|45	-0.26	0.02	0.04	-2.6	0.2	0.4
53|45	-0.19	-0.14	-0.19	-1.9	-1.4	-1.9
53|45	-0.07	-0.46	-0.39	-0.7	-4.6	-3.9
53|45	0.02	-0.65	-0.12	0.2	-6.5	-1.2
53|45	0.24	-0.61	-0.21	2.4	-6.1	-2.1
53|45	0.04	-0.24	0.12	0.4	-2.4	1.2
53|46	-0.31	-0.04	0.43	-3.1	-0.4	4.3
53|46	-0.31	-0.19	0.12	-3.1	-1.9	1.2
53|46	-0.02	-0.46	-0.09	-0.2	-4.6	-0.9
53|46	0.21	-0.46	-0.24	2.1	-4.6	-2.4
53|46	0.02	-0.29	0.34	0.2	-2.9	3.4
53|46	-0.17	0.02	0.39	-1.7	0.2	3.9
53|46	-0.31	-0.04	0.36	-3.1	-0.4	3.6
53|46	-0.31	-0.24	0.14	-3.1	-2.4	1.4
53|46	-0.14	-0.34	0.12	-1.4	-3.4	1.2
53|46	0	-0.04	0.09	0	-0.4	0.9
53|46	0.04	0.41	0.31	0.4	4.1	3.1
53|46	0.02	0.63	0.34	0.2	6.3	3.4
53|46	-0.02	0.53	0.48	-0.2	5.3	4.8
53|46	-0.07	0.17	0.41	-0.7	1.7	4.1
53|46	-0.12	-0.07	0.14	-1.2	-0.7	1.4
53|46	-0.24	-0.19	0.36	-2.4	-1.9	3.6
53|46	-0.07	-0.17	0.09	-0.7	-1.7	0.9
53|46	-0.07	-0.07	0.19	-0.7	-0.7	1.9
53|46	-0.12	0.02	0.29	-1.2	0.2	2.9
53|46	-0.17	0.09	0.19	-1.7	0.9	1.9
53|46	0	0.09	-0.02	0	0.9	-0.2
53|46	0.07	0.04	-0.09	0.7	0.4	-0.9
53|46	0.04	0	0.02	0.4	0	0.2
53|46	0	-0.07	-0.04	0	-0.7	-0.4
53|46	0.12	-0.14	-0.09	1.2	-1.4	-0.9
53|46	-0.19	-0.19	-0.09	-1.9	-1.9	-0.9
53|46	-0.14	-0.29	-0.04	-1.4	-2.9	-0.4
53|46	-0.04	-0.24	-0.21	-0.4	-2.4	-2.1
53|46	-0.04	-0.14	-0.02	-0.4	-1.4	-0.2
53|46	-0.12	0	-0.09	-1.2	0	-0.9
53|46	-0.12	0.07	-0.04	-1.2	0.7	-0.4
53|46	-0.09	0.07	0.07	-0.9	0.7	0.7

53|46	0.12	0.09	-0.14	1.2	0.9	-1.4
53|46	0.12	0.14	-0.07	1.2	1.4	-0.7
53|46	-0.14	0.24	0.19	-1.4	2.4	1.9
53|46	-0.07	0.14	0.12	-0.7	1.4	1.2
53|46	-0.04	0	-0.14	-0.4	0	-1.4
53|46	-0.12	-0.07	-0.04	-1.2	-0.7	-0.4
53|46	-0.17	-0.07	-0.02	-1.7	-0.7	-0.2
53|46	-0.02	0	-0.26	-0.2	0	-2.6
53|46	-0.04	0.04	-0.14	-0.4	0.4	-1.4
53|46	-0.19	0.04	0.04	-1.9	0.4	0.4
53|46	0.02	-0.02	-0.12	0.2	-0.2	-1.2
53|46	0.12	0.02	-0.34	1.2	0.2	-3.4
53|46	-0.17	0.17	0.14	-1.7	1.7	1.4
53|46	-0.17	0.14	0	-1.7	1.4	0
53|46	0.12	-0.07	-0.31	1.2	-0.7	-3.1
53|46	0.04	-0.19	-0.21	0.4	-1.9	-2.1
53|46	0.07	-0.19	-0.19	0.7	-1.9	-1.9
53|46	0.12	-0.19	-0.34	1.2	-1.9	-3.4
53|46	-0.12	-0.21	-0.14	-1.2	-2.1	-1.4
53|46	-0.31	-0.34	0.04	-3.1	-3.4	0.4
53|46	-0.12	-0.56	-0.34	-1.2	-5.6	-3.4
53|46	0.07	-0.58	-0.19	0.7	-5.8	-1.9
53|46	0.02	-0.36	0.31	0.2	-3.6	3.1
53|46	-0.07	-0.07	0.41	-0.7	-0.7	4.1
53|46	-0.04	-0.04	0.14	-0.4	-0.4	1.4
53|46	-0.04	-0.19	0.17	-0.4	-1.9	1.7
53|46	-0.04	-0.39	0.09	-0.4	-3.9	0.9
53|46	-0.07	-0.39	0.29	-0.7	-3.9	2.9
53|46	-0.21	-0.21	0.26	-2.1	-2.1	2.6
53|46	-0.29	-0.09	0.24	-2.9	-0.9	2.4
53|46	-0.19	-0.04	0.36	-1.9	-0.4	3.6
53|46	-0.02	0	0.17	-0.2	0	1.7
53|46	0.07	0.12	0.31	0.7	1.2	3.1
53|46	0.04	0.36	0.39	0.4	3.6	3.9
53|46	-0.04	0.46	0.48	-0.4	4.6	4.8
53|46	-0.04	0.24	0.46	-0.4	2.4	4.6
53|46	-0.14	0	0.09	-1.4	0	0.9
53|46	-0.21	-0.14	0.14	-2.1	-1.4	1.4
53|46	-0.07	-0.17	0.19	-0.7	-1.7	1.9
53|46	-0.12	-0.07	0.31	-1.2	-0.7	3.1
53|46	-0.14	-0.02	0.21	-1.4	-0.2	2.1
53|46	0.04	-0.19	0.46	0.4	-1.9	4.6
53|46	0	-0.07	-0.12	0	-0.7	-1.2

53|46	-0.09	-0.07	-0.24	-0.9	-0.7	-2.4
53|46	-0.09	-0.02	0.07	-0.9	-0.2	0.7
53|46	-0.02	0.04	0.12	-0.2	0.4	1.2
53|46	-0.04	-0.02	-0.14	-0.4	-0.2	-1.4
53|46	-0.12	-0.07	-0.02	-1.2	-0.7	-0.2
53|46	-0.19	-0.07	-0.04	-1.9	-0.7	-0.4
53|46	-0.12	-0.09	-0.07	-1.2	-0.9	-0.7
53|46	-0.04	-0.07	0.07	-0.4	-0.7	0.7
53|46	-0.12	-0.02	0.09	-1.2	-0.2	0.9
53|46	-0.04	-0.02	-0.04	-0.4	-0.2	-0.4
53|46	0	0.07	0	0	0.7	0
53|46	-0.02	0.04	0	-0.2	0.4	0
53|46	0.02	0.07	-0.04	0.2	0.7	-0.4
53|46	-0.09	0.12	0	-0.9	1.2	0
53|46	-0.17	0.07	-0.02	-1.7	0.7	-0.2
53|46	-0.07	-0.07	-0.17	-0.7	-0.7	-1.7
53|46	-0.07	-0.12	-0.14	-0.7	-1.2	-1.4
53|46	-0.17	-0.12	-0.12	-1.7	-1.2	-1.2
53|46	-0.02	-0.09	-0.26	-0.2	-0.9	-2.6
53|46	-0.02	-0.02	-0.21	-0.2	-0.2	-2.1
53|46	-0.21	0.04	0.04	-2.1	0.4	0.4
53|46	-0.07	-0.02	-0.17	-0.7	-0.2	-1.7
53|46	0.07	-0.04	-0.29	0.7	-0.4	-2.9
53|46	-0.09	0.07	0.04	-0.9	0.7	0.4
53|46	-0.17	0.14	0.17	-1.7	1.4	1.7
53|46	-0.02	0.09	-0.14	-0.2	0.9	-1.4
53|46	0.17	-0.07	-0.31	1.7	-0.7	-3.1
53|46	0.09	-0.09	-0.04	0.9	-0.9	-0.4
53|46	-0.04	-0.04	-0.04	-0.4	-0.4	-0.4
53|46	-0.14	-0.17	-0.04	-1.4	-1.7	-0.4
53|46	-0.19	-0.36	-0.14	-1.9	-3.6	-1.4
53|46	-0.12	-0.58	-0.12	-1.2	-5.8	-1.2
53|46	0.12	-0.65	-0.21	1.2	-6.5	-2.1
53|46	0.14	-0.43	0	1.4	-4.3	0
53|46	-0.07	-0.12	0.26	-0.7	-1.2	2.6
53|46	-0.29	-0.02	0.14	-2.9	-0.2	1.4
53|46	-0.17	-0.29	-0.07	-1.7	-2.9	-0.7
53|46	-0.04	-0.56	-0.09	-0.4	-5.6	-0.9
53|46	0.04	-0.58	-0.02	0.4	-5.8	-0.2
53|46	-0.04	-0.29	0.17	-0.4	-2.9	1.7
53|46	-0.19	-0.02	0.48	-1.9	-0.2	4.8
53|46	-0.21	0.02	0.39	-2.1	0.2	3.9
53|46	-0.14	0	0.17	-1.4	0	1.7

53|46	0.04	0.04	0.02	0.4	0.4	0.2
53|46	0.04	0.31	0.24	0.4	3.1	2.4
53|46	0	0.48	0.43	0	4.8	4.3
53|46	-0.04	0.41	0.39	-0.4	4.1	3.9
53|46	-0.04	0.09	0.07	-0.4	0.9	0.7
53|46	-0.02	-0.19	0.17	-0.2	-1.9	1.7
53|46	-0.07	-0.26	0.34	-0.7	-2.6	3.4
53|46	-0.19	-0.12	0.04	-1.9	-1.2	0.4
53|46	-0.19	-0.02	0.14	-1.9	-0.2	1.4
53|46	-0.19	0	0.48	-1.9	0	4.8
53|46	-0.04	-0.02	0.04	-0.4	-0.2	0.4
53|46	0.09	-0.04	-0.12	0.9	-0.4	-1.2
53|46	-0.02	0.09	0.02	-0.2	0.9	0.2
53|46	-0.17	0.14	0	-1.7	1.4	0
53|46	-0.12	-0.04	-0.12	-1.2	-0.4	-1.2
53|46	-0.04	-0.24	-0.17	-0.4	-2.4	-1.7
53|46	-0.09	-0.26	0.02	-0.9	-2.6	0.2
53|46	-0.14	-0.09	0.12	-1.4	-0.9	1.2
53|46	-0.12	0.02	0.09	-1.2	0.2	0.9
53|46	-0.07	0.07	0.09	-0.7	0.7	0.9
53|46	0	-0.04	0	0	-0.4	0
53|46	-0.04	-0.04	-0.04	-0.4	-0.4	-0.4
53|46	-0.04	0.02	-0.02	-0.4	0.2	-0.2
53|46	-0.09	0.14	0.07	-0.9	1.4	0.7
53|46	-0.14	0.14	0.07	-1.4	1.4	0.7
53|46	-0.12	-0.02	-0.04	-1.2	-0.2	-0.4
53|46	0.07	-0.17	-0.26	0.7	-1.7	-2.6
53|46	0	-0.14	-0.02	0	-1.4	-0.2
53|46	-0.17	-0.02	0.17	-1.7	-0.2	1.7
53|46	-0.17	-0.02	0	-1.7	-0.2	0
53|46	-0.09	-0.14	-0.09	-0.9	-1.4	-0.9
53|46	-0.19	-0.14	0.04	-1.9	-1.4	0.4
53|46	-0.04	-0.12	-0.04	-0.4	-1.2	-0.4
53|46	0.09	0.09	-0.14	0.9	0.9	-1.4
53|46	-0.14	0.31	0.09	-1.4	3.1	0.9
53|46	-0.17	0.26	0.02	-1.7	2.6	0.2
53|46	0.17	0.02	-0.26	1.7	0.2	-2.6
53|46	0.29	-0.12	-0.43	2.9	-1.2	-4.3
53|46	-0.12	0	0.14	-1.2	0	1.4
53|46	-0.31	0.02	0.19	-3.1	0.2	1.9
53|46	-0.12	-0.24	-0.31	-1.2	-2.4	-3.1
53|46	0.07	-0.56	-0.12	0.7	-5.6	-1.2
53|46	0.12	-0.63	0.04	1.2	-6.3	0.4

53|46	0.14	-0.43	-0.09	1.4	-4.3	-0.9
53|46	-0.09	-0.12	0.75	-0.9	-1.2	7.5
53|46	-0.36	-0.07	0.26	-3.6	-0.7	2.6
53|46	-0.21	-0.34	-0.04	-2.1	-3.4	-0.4
53|46	0.07	-0.61	-0.17	0.7	-6.1	-1.7
53|46	0.09	-0.51	-0.07	0.9	-5.1	-0.7
53|46	-0.04	-0.19	0.39	-0.4	-1.9	3.9
53|46	-0.14	-0.04	0.31	-1.4	-0.4	3.1
53|46	-0.24	-0.07	0.29	-2.4	-0.7	2.9
53|46	-0.14	-0.19	0.17	-1.4	-1.9	1.7
53|46	-0.02	-0.07	0.02	-0.2	-0.7	0.2
53|46	0	0.19	0.56	0	1.9	5.6
53|46	0.02	0.48	0.48	0.2	4.8	4.8
53|46	0.02	0.43	0.19	0.2	4.3	1.9
53|46	0	0.17	0.41	0	1.7	4.1
53|46	-0.07	-0.12	0.12	-0.7	-1.2	1.2
53|46	-0.21	-0.14	-0.31	-2.1	-1.4	-3.1
53|46	-0.12	-0.12	-0.04	-1.2	-1.2	-0.4
53|46	-0.09	-0.02	0.17	-0.9	-0.2	1.7
53|46	-0.17	0.04	0.24	-1.7	0.4	2.4
53|46	-0.09	0.02	0.26	-0.9	0.2	2.6
53|46	-0.07	-0.02	0.12	-0.7	-0.2	1.2
53|46	-0.07	-0.07	-0.02	-0.7	-0.7	-0.2
53|46	-0.04	-0.04	-0.07	-0.4	-0.4	-0.7
53|46	-0.07	0	-0.09	-0.7	0	-0.9
53|46	-0.04	0	-0.14	-0.4	0	-1.4
53|46	-0.12	-0.02	0	-1.2	-0.2	0
53|46	-0.14	-0.07	0	-1.4	-0.7	0
53|46	-0.02	-0.09	-0.07	-0.2	-0.9	-0.7
53|46	-0.09	-0.02	0	-0.9	-0.2	0
53|46	-0.09	-0.02	0.07	-0.9	-0.2	0.7
53|46	-0.02	-0.02	-0.04	-0.2	-0.2	-0.4
53|46	-0.12	-0.04	0.07	-1.2	-0.4	0.7
53|46	-0.02	-0.07	-0.02	-0.2	-0.7	-0.2
53|46	0.09	-0.02	-0.14	0.9	-0.2	-1.4
53|46	-0.07	0.04	0.04	-0.7	0.4	0.4
53|46	-0.17	0.07	0.02	-1.7	0.7	0.2
53|46	-0.04	-0.07	-0.24	-0.4	-0.7	-2.4
53|46	-0.12	-0.14	-0.21	-1.2	-1.4	-2.1
53|46	-0.19	-0.12	-0.07	-1.9	-1.2	-0.7
53|46	-0.07	-0.09	-0.24	-0.7	-0.9	-2.4
53|46	-0.04	-0.02	-0.12	-0.4	-0.2	-1.2
53|46	-0.19	0.02	0.07	-1.9	0.2	0.7

53|46	-0.02	0	-0.14	-0.2	0	-1.4
53|46	0.12	0.04	-0.24	1.2	0.4	-2.4
53|46	-0.14	0.19	0.19	-1.4	1.9	1.9
53|46	-0.17	0.24	0	-1.7	2.4	0
53|46	0.14	0.14	-0.24	1.4	1.4	-2.4
53|46	0.07	0.04	-0.07	0.7	0.4	-0.7
53|46	-0.09	-0.02	0	-0.9	-0.2	0
53|46	0.07	-0.09	-0.29	0.7	-0.9	-2.9
53|46	0	-0.24	-0.12	0	-2.4	-1.2
53|46	-0.21	-0.34	-0.02	-2.1	-3.4	-0.2
53|46	-0.17	-0.53	-0.26	-1.7	-5.3	-2.6
53|46	-0.04	-0.56	-0.12	-0.4	-5.6	-1.2
53|46	0	-0.53	-0.04	0	-5.3	-0.4
53|46	-0.09	-0.24	0.19	-0.9	-2.4	1.9
53|46	-0.02	-0.17	0.12	-0.2	-1.7	1.2
53|46	0.07	-0.21	0.07	0.7	-2.1	0.7
53|46	-0.04	-0.21	0.17	-0.4	-2.1	1.7
53|46	-0.12	-0.24	0.19	-1.2	-2.4	1.9
53|46	-0.17	-0.21	0.24	-1.7	-2.1	2.4
53|46	-0.24	-0.17	0.21	-2.4	-1.7	2.1
53|46	-0.14	-0.17	0.21	-1.4	-1.7	2.1
53|46	0	-0.12	0.21	0	-1.2	2.1
53|46	0.04	0.09	0.53	0.4	0.9	5.3
53|46	0.02	0.31	0.17	0.2	3.1	1.7
53|46	0	0.34	-0.04	0	3.4	-0.4
53|46	-0.14	0.24	0.34	-1.4	2.4	3.4
53|46	-0.07	0.04	0.14	-0.7	0.4	1.4
53|46	-0.07	-0.07	-0.24	-0.7	-0.7	-2.4
53|46	-0.17	-0.12	0.12	-1.7	-1.2	1.2
53|46	-0.17	-0.04	0.21	-1.7	-0.4	2.1
53|46	-0.17	-0.02	0.17	-1.7	-0.2	1.7
53|46	0.14	-0.02	0.09	1.4	-0.2	0.9
53|46	0.04	0.12	-0.31	0.4	1.2	-3.1
53|46	-0.12	0.24	-0.07	-1.2	2.4	-0.7
53|46	-0.07	0.21	0	-0.7	2.1	0
53|46	-0.04	0.07	0.04	-0.4	0.7	0.4
53|46	-0.04	-0.09	-0.21	-0.4	-0.9	-2.1
53|46	-0.07	-0.21	-0.04	-0.7	-2.1	-0.4
53|46	-0.14	-0.21	0.12	-1.4	-2.1	1.2
53|46	-0.12	-0.14	-0.09	-1.2	-1.4	-0.9
53|46	-0.12	-0.07	0.07	-1.2	-0.7	0.7
53|46	-0.04	-0.07	0.17	-0.4	-0.7	1.7
53|46	0	-0.04	0.02	0	-0.4	0.2

53|46	-0.04	0	-0.02	-0.4	0	-0.2
53|46	0.04	0.02	-0.12	0.4	0.2	-1.2
53|46	0	0.04	-0.17	0	0.4	-1.7
53|46	-0.12	0	-0.07	-1.2	0	-0.7
53|46	-0.24	0.02	-0.04	-2.4	0.2	-0.4
53|46	-0.14	-0.02	-0.12	-1.4	-0.2	-1.2
53|46	-0.09	-0.04	-0.14	-0.9	-0.4	-1.4
53|46	-0.04	-0.07	-0.12	-0.4	-0.7	-1.2
53|46	-0.02	-0.07	-0.12	-0.2	-0.7	-1.2
53|46	-0.07	-0.02	-0.14	-0.7	-0.2	-1.4
53|46	-0.21	0.09	0.04	-2.1	0.9	0.4
53|46	-0.12	0.09	0.04	-1.2	0.9	0.4
53|46	0.02	0.12	-0.17	0.2	1.2	-1.7
53|46	0.09	0.17	0	0.9	1.7	0
53|46	-0.04	0.24	0.07	-0.4	2.4	0.7
53|46	-0.02	0.17	-0.17	-0.2	1.7	-1.7
53|46	0.14	0	-0.34	1.4	0	-3.4
53|46	0.02	-0.12	-0.02	0.2	-1.2	-0.2
53|46	-0.19	-0.21	-0.02	-1.9	-2.1	-0.2
53|46	-0.14	-0.36	-0.14	-1.4	-3.6	-1.4
53|46	-0.04	-0.51	-0.21	-0.4	-5.1	-2.1
53|46	-0.14	-0.51	0.09	-1.4	-5.1	0.9
53|46	0	-0.48	-0.07	0	-4.8	-0.7
53|46	0.14	-0.31	-0.17	1.4	-3.1	-1.7
53|46	-0.09	-0.04	0.51	-0.9	-0.4	5.1
53|46	-0.14	0.02	-0.14	-1.4	0.2	-1.4
53|46	-0.07	-0.09	-0.7	-0.7	-0.9	-7
53|46	-0.04	-0.31	-0.19	-0.4	-3.1	-1.9
53|46	-0.04	0.07	0.09	-0.4	0.7	0.9
53|46	-0.12	0.29	0.24	-1.2	2.9	2.4
53|46	0.04	0.24	0.14	0.4	2.4	1.4
53|46	0.02	0.14	0.21	0.2	1.4	2.1
53|46	-0.12	0	0.34	-1.2	0	3.4
53|46	-0.12	-0.12	0.24	-1.2	-1.2	2.4
53|46	-0.12	-0.12	0.21	-1.2	-1.2	2.1
53|46	-0.24	-0.07	0.41	-2.4	-0.7	4.1
53|46	-0.14	-0.12	0.24	-1.4	-1.2	2.4
53|46	0.02	-0.07	0.02	0.2	-0.7	0.2
53|46	0	0.02	0.07	0	0.2	0.7
53|46	-0.12	0.14	0.07	-1.2	1.4	0.7
53|46	-0.14	0.09	-0.07	-1.4	0.9	-0.7
53|46	-0.02	-0.02	-0.19	-0.2	-0.2	-1.9
53|46	-0.02	-0.12	-0.21	-0.2	-1.2	-2.1

53|46	0	-0.07	-0.04	0	-0.7	-0.4
53|46	-0.09	0.07	0.04	-0.9	0.7	0.4
53|46	-0.21	0.02	0.17	-2.1	0.2	1.7
53|46	-0.14	-0.09	0.12	-1.4	-0.9	1.2
53|46	0	-0.19	0.04	0	-1.9	0.4
53|46	0	-0.14	0.07	0	-1.4	0.7
53|46	0	-0.02	0.12	0	-0.2	1.2
53|46	-0.04	0.04	0.12	-0.4	0.4	1.2
53|46	-0.17	0.04	0.12	-1.7	0.4	1.2
53|46	-0.17	-0.09	0	-1.7	-0.9	0
53|46	-0.09	-0.17	-0.12	-0.9	-1.7	-1.2
53|46	-0.07	-0.14	-0.12	-0.7	-1.4	-1.2
53|46	-0.02	-0.02	-0.12	-0.2	-0.2	-1.2
53|46	-0.12	0.07	-0.07	-1.2	0.7	-0.7
53|46	-0.17	0.07	0	-1.7	0.7	0
53|46	-0.14	0.02	-0.14	-1.4	0.2	-1.4
53|46	-0.04	0	-0.21	-0.4	0	-2.1
53|46	-0.02	0	-0.04	-0.2	0	-0.4
53|47	0	0.02	0	0	0.2	0
53|47	-0.02	0.09	0.02	-0.2	0.9	0.2
53|47	-0.17	0.14	0.12	-1.7	1.4	1.2
53|47	-0.21	0	0.17	-2.1	0	1.7
53|47	0.07	-0.09	-0.17	0.7	-0.9	-1.7
53|47	0.31	-0.09	-0.26	3.1	-0.9	-2.6
53|47	-0.04	0.12	0.21	-0.4	1.2	2.1
53|47	-0.34	0.12	0.24	-3.4	1.2	2.4
53|47	-0.17	-0.17	-0.26	-1.7	-1.7	-2.6
53|47	-0.04	-0.43	-0.17	-0.4	-4.3	-1.7
53|47	0.14	-0.56	-0.04	1.4	-5.6	-0.4
53|47	0.21	-0.36	0	2.1	-3.6	0
53|47	-0.12	-0.12	0.48	-1.2	-1.2	4.8
53|47	-0.31	-0.19	0.43	-3.1	-1.9	4.3
53|47	-0.24	-0.46	0.12	-2.4	-4.6	1.2
53|47	-0.04	-0.68	-0.09	-0.4	-6.8	-0.9
53|47	0.19	-0.56	-0.24	1.9	-5.6	-2.4
53|47	0.07	-0.19	0.21	0.7	-1.9	2.1
53|47	-0.17	0.09	0.31	-1.7	0.9	3.1
53|47	-0.14	-0.02	0.17	-1.4	-0.2	1.7
53|47	-0.12	-0.19	-0.12	-1.2	-1.9	-1.2
53|47	-0.12	-0.24	0.07	-1.2	-2.4	0.7
53|47	0.04	0.04	0.04	0.4	0.4	0.4
53|47	0.02	0.31	0.34	0.2	3.1	3.4
53|47	-0.04	0.34	0.41	-0.4	3.4	4.1

53|47	-0.04	0.12	0.29	-0.4	1.2	2.9
53|47	-0.09	-0.09	0.14	-0.9	-0.9	1.4
53|47	-0.21	-0.12	0.19	-2.1	-1.2	1.9
53|47	-0.19	-0.07	0.29	-1.9	-0.7	2.9
53|47	-0.02	-0.04	0.14	-0.2	-0.4	1.4
53|47	-0.04	0	0.26	-0.4	0	2.6
53|47	-0.09	0	0.21	-0.9	0	2.1
53|47	-0.07	0.02	0.04	-0.7	0.2	0.4
53|47	-0.12	0.07	-0.02	-1.2	0.7	-0.2
53|47	0	0.07	-0.07	0	0.7	-0.7
53|47	0	0	-0.09	0	0	-0.9
53|47	0	-0.04	-0.04	0	-0.4	-0.4
53|47	-0.14	0	0.07	-1.4	0	0.7
53|47	-0.17	-0.02	0.14	-1.7	-0.2	1.4
53|47	-0.07	-0.07	0	-0.7	-0.7	0
53|47	-0.02	-0.14	0	-0.2	-1.4	0
53|47	-0.07	-0.12	0.07	-0.7	-1.2	0.7
53|47	-0.09	-0.07	0.04	-0.9	-0.7	0.4
53|47	-0.07	-0.07	0.02	-0.7	-0.7	0.2
53|47	-0.12	-0.04	0.07	-1.2	-0.4	0.7
53|47	-0.04	-0.07	-0.09	-0.4	-0.7	-0.9
53|47	0.07	-0.07	-0.24	0.7	-0.7	-2.4
53|47	-0.04	0	-0.04	-0.4	0	-0.4
53|47	-0.19	0.04	-0.07	-1.9	0.4	-0.7
53|47	-0.09	0.02	-0.17	-0.9	0.2	-1.7
53|47	-0.07	-0.04	-0.19	-0.7	-0.4	-1.9
53|47	-0.12	-0.07	-0.07	-1.2	-0.7	-0.7
53|47	-0.04	-0.07	-0.19	-0.4	-0.7	-1.9
53|47	-0.07	0	-0.12	-0.7	0	-1.2
53|47	-0.09	0.02	0.02	-0.9	0.2	0.2
53|47	-0.02	-0.04	-0.04	-0.2	-0.4	-0.4
53|47	0.04	0.02	-0.04	0.4	0.2	-0.4
53|47	-0.12	0.14	0.07	-1.2	1.4	0.7
53|47	-0.12	0.07	0	-1.2	0.7	0
53|47	-0.07	0	-0.04	-0.7	0	-0.4
53|47	0.02	-0.04	-0.31	0.2	-0.4	-3.1
53|47	0.02	-0.07	-0.12	0.2	-0.7	-1.2
53|47	0.07	-0.04	-0.17	0.7	-0.4	-1.7
53|47	0	-0.02	-0.17	0	-0.2	-1.7
53|47	-0.19	-0.12	-0.02	-1.9	-1.2	-0.2
53|47	-0.12	-0.34	-0.02	-1.2	-3.4	-0.2
53|47	0.02	-0.51	0	0.2	-5.1	0
53|47	-0.02	-0.48	0.07	-0.2	-4.8	0.7

53|47	-0.09	-0.46	0.21	-0.9	-4.6	2.1
53|47	-0.02	-0.36	0.17	-0.2	-3.6	1.7
53|47	-0.04	-0.34	-0.12	-0.4	-3.4	-1.2
53|47	-0.07	-0.36	-0.12	-0.7	-3.6	-1.2
53|47	0	-0.31	-0.04	0	-3.1	-0.4
53|47	-0.02	-0.19	0.07	-0.2	-1.9	0.7
53|47	-0.14	-0.07	-0.26	-1.4	-0.7	-2.6
53|47	-0.19	-0.04	0.19	-1.9	-0.4	1.9
53|47	-0.14	-0.04	0.04	-1.4	-0.4	0.4
53|47	-0.04	-0.02	0.04	-0.4	-0.2	0.4
53|47	0.02	0.12	0.24	0.2	1.2	2.4
53|47	-0.02	0.24	0.43	-0.2	2.4	4.3
53|47	-0.09	0.21	0.39	-0.9	2.1	3.9
53|47	-0.02	-0.34	0.29	-0.2	-3.4	2.9
53|47	-0.14	-0.19	0.43	-1.4	-1.9	4.3
53|47	-0.17	-0.21	0.34	-1.7	-2.1	3.4
53|47	-0.04	-0.41	0.14	-0.4	-4.1	1.4
53|47	0.02	-0.46	-0.24	0.2	-4.6	-2.4
53|47	0.02	-0.29	-0.04	0.2	-2.9	-0.4
53|47	-0.09	-0.12	0.04	-0.9	-1.2	0.4
53|47	-0.19	0	0.07	-1.9	0	0.7
53|47	-0.14	-0.07	0.09	-1.4	-0.7	0.9
53|47	-0.07	-0.07	-0.04	-0.7	-0.7	-0.4
53|47	-0.07	0.04	0.14	-0.7	0.4	1.4
53|47	-0.07	0.29	0.31	-0.7	2.9	3.1
53|47	-0.02	0.29	0.39	-0.2	2.9	3.9
53|47	-0.07	0.14	0.39	-0.7	1.4	3.9
53|47	-0.17	-0.02	0.39	-1.7	-0.2	3.9
53|47	-0.17	-0.09	0.24	-1.7	-0.9	2.4
53|47	-0.17	-0.07	0.26	-1.7	-0.7	2.6
53|47	-0.07	-0.02	0.17	-0.7	-0.2	1.7
53|47	-0.09	0	0.19	-0.9	0	1.9
53|47	-0.17	0	0.17	-1.7	0	1.7
53|47	-0.09	0.02	-0.07	-0.9	0.2	-0.7
53|47	0	0.04	-0.12	0	0.4	-1.2
53|47	-0.09	0.09	0	-0.9	0.9	0
53|47	-0.14	0.07	0	-1.4	0.7	0
53|47	-0.07	-0.04	-0.09	-0.7	-0.4	-0.9
53|47	-0.09	-0.12	-0.07	-0.9	-1.2	-0.7
53|47	-0.17	-0.12	-0.02	-1.7	-1.2	-0.2
53|47	-0.14	-0.12	0	-1.4	-1.2	0
53|47	-0.09	-0.07	0	-0.9	-0.7	0
53|47	-0.07	-0.02	0.09	-0.7	-0.2	0.9

53|47	-0.09	-0.04	0.09	-0.9	-0.4	0.9
53|47	-0.04	-0.04	0.09	-0.4	-0.4	0.9
53|47	-0.04	-0.02	-0.04	-0.4	-0.2	-0.4
53|47	-0.17	0	0.09	-1.7	0	0.9
53|47	-0.24	-0.02	0.19	-2.4	-0.2	1.9
53|47	-0.17	-0.07	-0.09	-1.7	-0.7	-0.9
53|47	-0.04	-0.09	-0.09	-0.4	-0.9	-0.9
53|47	-0.09	0	0.09	-0.9	0	0.9
53|47	-0.09	0.34	0.07	-0.9	3.4	0.7
53|47	-0.17	0.12	0.12	-1.7	1.2	1.2
53|47	-0.24	0.02	0.09	-2.4	0.2	0.9
53|47	-0.14	-0.14	-0.02	-1.4	-1.4	-0.2
53|47	0	-0.17	-0.09	0	-1.7	-0.9
53|47	0	0.02	0.07	0	0.2	0.7
53|47	-0.17	0.21	0.14	-1.7	2.1	1.4
53|47	-0.31	0.19	0.26	-3.1	1.9	2.6
53|47	-0.07	0	-0.14	-0.7	0	-1.4
53|47	0.21	-0.17	-0.29	2.1	-1.7	-2.9
53|47	-0.09	-0.02	0.12	-0.9	-0.2	1.2
53|47	-0.34	0.04	0.48	-3.4	0.4	4.8
53|47	-0.17	-0.14	0.14	-1.7	-1.4	1.4
53|47	0.04	-0.41	0.04	0.4	-4.1	0.4
53|47	-0.07	-0.51	0.31	-0.7	-5.1	3.1
53|47	0.09	-0.43	-0.02	0.9	-4.3	-0.2
53|47	-0.07	-0.12	0.17	-0.7	-1.2	1.7
53|47	-0.36	-0.02	0.34	-3.6	-0.2	3.4
53|47	-0.29	-0.21	0.04	-2.9	-2.1	0.4
53|47	0.02	-0.56	-0.17	0.2	-5.6	-1.7
53|47	0.07	-0.56	-0.26	0.7	-5.6	-2.6
53|47	-0.12	-0.31	0.31	-1.2	-3.1	3.1
53|47	-0.09	-0.09	0.24	-0.9	-0.9	2.4
53|47	-0.17	-0.09	0.34	-1.7	-0.9	3.4
53|47	-0.21	-0.12	0.17	-2.1	-1.2	1.7
53|47	-0.07	-0.09	0.04	-0.7	-0.9	0.4
53|47	0.07	0.07	0.04	0.7	0.7	0.4
53|47	-0.09	0.34	0.41	-0.9	3.4	4.1
53|47	-0.17	0.39	0.51	-1.7	3.9	5.1
53|47	-0.09	0.17	0.26	-0.9	1.7	2.6
53|47	-0.07	-0.09	0.26	-0.7	-0.9	2.6
53|47	-0.14	-0.14	0.34	-1.4	-1.4	3.4
53|47	-0.29	-0.07	0.34	-2.9	-0.7	3.4
53|47	-0.19	-0.02	0.26	-1.9	-0.2	2.6
53|47	-0.14	0	0.26	-1.4	0	2.6

53|47	-0.12	-0.02	0.21	-1.2	-0.2	2.1
53|47	-0.09	0	0.17	-0.9	0	1.7
53|47	-0.12	0.04	0.14	-1.2	0.4	1.4
53|47	-0.14	0.04	0	-1.4	0.4	0
53|47	-0.12	-0.02	-0.02	-1.2	-0.2	-0.2
53|47	-0.09	-0.09	0	-0.9	-0.9	0
53|47	-0.14	-0.09	0.04	-1.4	-0.9	0.4
53|47	-0.09	-0.04	0.04	-0.9	-0.4	0.4
53|47	-0.07	-0.02	0.07	-0.7	-0.2	0.7
53|47	-0.09	-0.07	0.09	-0.9	-0.7	0.9
53|47	-0.17	-0.12	0.07	-1.7	-1.2	0.7
53|47	-0.17	-0.14	0.09	-1.7	-1.4	0.9
53|47	-0.12	-0.14	0.09	-1.2	-1.4	0.9
53|47	-0.14	-0.09	0.12	-1.4	-0.9	1.2
53|47	-0.09	-0.04	0.17	-0.9	-0.4	1.7
53|47	-0.04	-0.09	-0.04	-0.4	-0.9	-0.4
53|47	-0.09	0.02	-0.09	-0.9	0.2	-0.9
53|47	-0.26	0.14	0.12	-2.6	1.4	1.2
53|47	-0.14	0.12	-0.12	-1.4	1.2	-1.2
53|47	0.07	0	-0.12	0.7	0	-1.2
53|47	-0.04	0	0.04	-0.4	0	0.4
53|47	-0.26	0.04	0.21	-2.6	0.4	2.1
53|47	-0.17	0.02	0.04	-1.7	0.2	0.4
53|47	-0.04	-0.02	-0.04	-0.4	-0.2	-0.4
53|47	-0.14	-0.02	0.19	-1.4	-0.2	1.9
53|47	-0.09	0.02	0.14	-0.9	0.2	1.4
53|47	-0.07	0.14	0	-0.7	1.4	0
53|47	-0.14	0.12	0.14	-1.4	1.2	1.4
53|47	-0.07	-0.17	0	-0.7	-1.7	0
53|47	0	-0.12	-0.21	0	-1.2	-2.1
53|47	-0.02	-0.09	-0.07	-0.2	-0.9	-0.7
53|47	-0.07	0	0	-0.7	0	0
53|47	-0.02	0	-0.19	-0.2	0	-1.9
53|47	-0.17	-0.09	0.14	-1.7	-0.9	1.4
53|47	-0.26	-0.26	0.12	-2.6	-2.6	1.2
53|47	0.04	-0.36	-0.09	0.4	-3.6	-0.9
53|47	0.02	-0.36	0.26	0.2	-3.6	2.6
53|47	-0.24	-0.21	0.46	-2.4	-2.1	4.6
53|47	-0.14	-0.24	0.21	-1.4	-2.4	2.1
53|47	0.04	-0.31	-0.09	0.4	-3.1	-0.9
53|47	-0.09	-0.26	0.14	-0.9	-2.6	1.4
53|47	-0.21	-0.17	0.21	-2.1	-1.7	2.1
53|47	-0.07	-0.12	0.04	-0.7	-1.2	0.4

53|47	-0.12	-0.09	0.09	-1.2	-0.9	0.9
53|47	-0.17	-0.09	0.17	-1.7	-0.9	1.7
53|47	-0.09	-0.09	0.07	-0.9	-0.9	0.7
53|47	0.04	0	-0.07	0.4	0	-0.7
53|47	-0.02	0.12	0.34	-0.2	1.2	3.4
53|47	-0.04	0.17	0.36	-0.4	1.7	3.6
53|47	-0.14	0.14	0.43	-1.4	1.4	4.3
53|47	-0.12	0.02	0.31	-1.2	0.2	3.1
53|47	-0.02	-0.04	0.12	-0.2	-0.4	1.2
53|47	-0.12	-0.04	0.17	-1.2	-0.4	1.7
53|47	-0.19	0.04	0.34	-1.9	0.4	3.4
53|47	-0.14	0.02	0.26	-1.4	0.2	2.6
53|47	-0.02	-0.04	0.21	-0.2	-0.4	2.1
53|47	-0.14	-0.02	0.34	-1.4	-0.2	3.4
53|47	-0.14	0	0.46	-1.4	0	4.6
53|47	0.02	0.04	0.12	0.2	0.4	1.2
53|47	0.04	0.09	-0.02	0.4	0.9	-0.2
53|47	-0.17	0.09	0.29	-1.7	0.9	2.9
53|47	-0.19	-0.04	0.12	-1.9	-0.4	1.2
53|47	0	-0.04	-0.29	0	-0.4	-2.9
53|47	-0.09	-0.02	0	-0.9	-0.2	0
53|47	-0.17	0.02	0.12	-1.7	0.2	1.2
53|47	-0.12	0.02	0.02	-1.2	0.2	0.2
53|47	-0.02	0	-0.02	-0.2	0	-0.2
53|47	-0.17	0	0.17	-1.7	0	1.7
53|47	-0.07	-0.12	0	-0.7	-1.2	0
53|47	0.04	-0.12	-0.14	0.4	-1.2	-1.4
53|47	-0.12	-0.04	0.07	-1.2	-0.4	0.7
53|47	-0.17	0.04	0.31	-1.7	0.4	3.1
53|47	-0.17	0.04	0.09	-1.7	0.4	0.9
53|47	-0.14	0.02	0.07	-1.4	0.2	0.7
53|47	-0.07	0	-0.02	-0.7	0	-0.2
53|47	0.09	0	-0.09	0.9	0	-0.9
53|47	0	0.07	0.04	0	0.7	0.4
53|47	-0.21	0.12	0.29	-2.1	1.2	2.9
53|47	-0.17	0	0.21	-1.7	0	2.1
53|47	0.04	-0.09	-0.02	0.4	-0.9	-0.2
53|47	-0.12	-0.02	0.21	-1.2	-0.2	2.1
53|47	-0.14	0.04	0.14	-1.4	0.4	1.4
53|47	0.02	0.09	-0.04	0.2	0.9	-0.4
53|47	-0.02	0.09	0	-0.2	0.9	0
53|47	-0.12	0.07	0.04	-1.2	0.7	0.4
53|47	-0.07	0.07	-0.02	-0.7	0.7	-0.2

53|47	0.12	0.04	-0.17	1.2	0.4	-1.7
53|47	0.09	0.04	0.07	0.9	0.4	0.7
53|47	0	0.04	0.12	0	0.4	1.2
53|47	-0.07	0.02	0	-0.7	0.2	0
53|47	-0.14	-0.12	-0.02	-1.4	-1.2	-0.2
53|47	0.04	-0.26	0	0.4	-2.6	0
53|47	0.12	-0.29	-0.07	1.2	-2.9	-0.7
53|47	-0.09	0.29	-0.02	-0.9	2.9	-0.2
53|47	-0.07	0.14	-0.17	-0.7	1.4	-1.7
53|47	-0.07	-0.02	-0.12	-0.7	-0.2	-1.2
53|47	-0.12	-0.12	-0.07	-1.2	-1.2	-0.7
53|47	-0.07	-0.19	-0.12	-0.7	-1.9	-1.2
53|47	-0.14	-0.07	-0.07	-1.4	-0.7	-0.7
53|47	-0.17	0	0.02	-1.7	0	0.2
53|47	-0.04	0.04	-0.04	-0.4	0.4	-0.4
53|47	0.02	0.09	-0.19	0.2	0.9	-1.9
53|47	-0.07	0.12	-0.07	-0.7	1.2	-0.7
53|47	-0.07	0.19	-0.12	-0.7	1.9	-1.2
53|47	0.12	0.12	-0.26	1.2	1.2	-2.6
53|47	0.09	0.04	-0.19	0.9	0.4	-1.9
53|47	-0.14	0.04	0.04	-1.4	0.4	0.4
53|47	-0.14	-0.07	-0.09	-1.4	-0.7	-0.9
53|47	-0.17	-0.26	-0.07	-1.7	-2.6	-0.7
53|47	-0.02	-0.39	0.17	-0.2	-3.9	1.7
53|47	-0.02	-0.41	0	-0.2	-4.1	0
53|47	0.07	-0.43	-0.02	0.7	-4.3	-0.2
53|47	-0.04	-0.31	0.21	-0.4	-3.1	2.1
53|47	-0.14	-0.24	0.26	-1.4	-2.4	2.6
53|47	-0.09	-0.29	0.17	-0.9	-2.9	1.7
53|47	0.02	-0.36	-0.04	0.2	-3.6	-0.4
53|47	0	-0.31	0.02	0	-3.1	0.2
53|47	-0.04	-0.24	0	-0.4	-2.4	0
53|47	-0.12	-0.24	0.12	-1.2	-2.4	1.2
53|47	-0.14	-0.24	0.09	-1.4	-2.4	0.9
53|47	-0.09	-0.14	0.17	-0.9	-1.4	1.7
53|47	0.02	0.02	0.12	0.2	0.2	1.2
53|47	0.07	0.34	0.19	0.7	3.4	1.9
53|47	0.02	0.48	0.41	0.2	4.8	4.1
53|47	-0.07	0.39	0.46	-0.7	3.9	4.6
53|47	-0.02	0.09	0.29	-0.2	0.9	2.9
53|47	-0.14	-0.14	0.26	-1.4	-1.4	2.6
53|47	-0.24	-0.26	0.51	-2.4	-2.6	5.1
53|47	-0.09	-0.24	0.19	-0.9	-2.4	1.9

53|48	-0.02	-0.14	0.24	-0.2	-1.4	2.4
53|48	-0.12	0	0.26	-1.2	0	2.6
53|48	-0.14	0.12	0.02	-1.4	1.2	0.2
53|48	-0.04	0.14	-0.12	-0.4	1.4	-1.2
53|48	0.04	0.04	-0.12	0.4	0.4	-1.2
53|48	0	0.04	-0.09	0	0.4	-0.9
53|48	-0.02	-0.02	-0.04	-0.2	-0.2	-0.4
53|48	-0.14	-0.07	0.07	-1.4	-0.7	0.7
53|48	-0.17	-0.14	-0.14	-1.7	-1.4	-1.4
53|48	-0.17	-0.17	-0.09	-1.7	-1.7	-0.9
53|48	-0.07	-0.12	-0.07	-0.7	-1.2	-0.7
53|48	0	-0.14	-0.02	0	-1.4	-0.2
53|48	-0.02	-0.12	0	-0.2	-1.2	0
53|48	-0.12	-0.07	0.07	-1.2	-0.7	0.7
53|48	-0.14	-0.12	-0.04	-1.4	-1.2	-0.4
53|48	-0.17	-0.07	-0.04	-1.7	-0.7	-0.4
53|48	-0.19	0	-0.07	-1.9	0	-0.7
53|48	-0.02	0.04	-0.14	-0.2	0.4	-1.4
53|48	0.04	0.07	-0.12	0.4	0.7	-1.2
53|48	-0.12	0.07	0.02	-1.2	0.7	0.2
53|48	-0.21	0.02	-0.07	-2.1	0.2	-0.7
53|48	-0.17	-0.07	-0.29	-1.7	-0.7	-2.9
53|48	-0.17	-0.12	-0.26	-1.7	-1.2	-2.6
53|48	-0.14	-0.04	-0.21	-1.4	-0.4	-2.1
53|48	0	0.07	-0.29	0	0.7	-2.9
53|48	-0.04	0.26	-0.14	-0.4	2.6	-1.4
53|48	-0.14	0.26	-0.07	-1.4	2.6	-0.7
53|48	0.04	0.12	-0.26	0.4	1.2	-2.6
53|48	0.02	-0.02	-0.09	0.2	-0.2	-0.9
53|48	-0.21	-0.07	0.07	-2.1	-0.7	0.7
53|48	-0.17	-0.24	0.07	-1.7	-2.4	0.7
53|48	-0.12	-0.34	-0.12	-1.2	-3.4	-1.2
53|48	-0.21	-0.43	0.21	-2.1	-4.3	2.1
53|48	0.02	-0.46	0.07	0.2	-4.6	0.7
53|48	0.09	-0.26	0.02	0.9	-2.6	0.2
53|48	-0.14	-0.07	0.36	-1.4	-0.7	3.6
53|48	-0.21	-0.14	0.24	-2.1	-1.4	2.4
53|48	-0.02	-0.34	-0.04	-0.2	-3.4	-0.4
53|48	-0.04	-0.43	0.04	-0.4	-4.3	0.4
53|48	-0.07	-0.39	0.14	-0.7	-3.9	1.4
53|48	-0.02	-0.29	0.17	-0.2	-2.9	1.7
53|48	-0.14	-0.26	0.26	-1.4	-2.6	2.6
53|48	-0.26	-0.31	0.48	-2.6	-3.1	4.8

53|48	-0.21	-0.31	0.29	-2.1	-3.1	2.9
53|48	-0.02	0.14	0.14	-0.2	1.4	1.4
53|48	-0.09	0.14	0.41	-0.9	1.4	4.1
53|48	-0.09	0.36	0.51	-0.9	3.6	5.1
53|48	0.02	0.29	0.41	0.2	2.9	4.1
53|48	-0.07	0.12	0.43	-0.7	1.2	4.3
53|48	-0.19	-0.02	0.48	-1.9	-0.2	4.8
53|48	-0.12	-0.09	0.43	-1.2	-0.9	4.3
53|48	-0.09	-0.12	0.39	-0.9	-1.2	3.9
53|48	-0.29	-0.07	0.58	-2.9	-0.7	5.8
53|48	-0.19	-0.12	0.39	-1.9	-1.2	3.9
53|48	-0.12	-0.12	0.07	-1.2	-1.2	0.7
53|48	-0.17	-0.09	0.17	-1.7	-0.9	1.7
53|48	-0.14	-0.07	0.14	-1.4	-0.7	1.4
53|48	-0.14	-0.09	0.02	-1.4	-0.9	0.2
53|48	-0.07	-0.19	0.04	-0.7	-1.9	0.4
53|48	-0.04	-0.19	0.09	-0.4	-1.9	0.9
53|48	-0.21	-0.07	0.34	-2.1	-0.7	3.4
53|48	-0.19	0.04	0.26	-1.9	0.4	2.6
53|48	-0.04	-0.04	0.14	-0.4	-0.4	1.4
53|48	-0.17	-0.09	0.24	-1.7	-0.9	2.4
53|48	-0.21	-0.19	0.39	-2.1	-1.9	3.9
53|48	-0.04	-0.24	0.19	-0.4	-2.4	1.9
53|48	-0.14	-0.19	0.39	-1.4	-1.9	3.9
53|48	-0.21	-0.17	0.36	-2.1	-1.7	3.6
53|48	-0.12	-0.14	0.12	-1.2	-1.4	1.2
53|48	-0.09	-0.14	0	-0.9	-1.4	0
53|48	-0.26	-0.09	0.21	-2.6	-0.9	2.1
53|48	-0.07	-0.14	0.02	-0.7	-1.4	0.2
53|48	-0.02	-0.07	-0.12	-0.2	-0.7	-1.2
53|48	-0.24	0	0.24	-2.4	0	2.4
53|48	-0.26	-0.02	-0.02	-2.6	-0.2	-0.2
53|48	-0.12	-0.07	-0.09	-1.2	-0.7	-0.9
53|48	-0.21	-0.02	0.14	-2.1	-0.2	1.4
53|48	-0.17	0.02	0.14	-1.7	0.2	1.4
53|48	-0.02	0.04	0.12	-0.2	0.4	1.2
53|48	-0.07	0.17	0.19	-0.7	1.7	1.9
53|48	-0.07	0.09	0.24	-0.7	0.9	2.4
53|48	-0.17	0	0.12	-1.7	0	1.2
53|48	-0.12	-0.12	0.24	-1.2	-1.2	2.4
53|48	0.02	-0.26	0.02	0.2	-2.6	0.2
53|48	-0.17	-0.24	0.26	-1.7	-2.4	2.6
53|48	-0.34	-0.24	0.43	-3.4	-2.4	4.3

53|48	-0.07	-0.29	0	-0.7	-2.9	0
53|48	-0.07	-0.39	0.12	-0.7	-3.9	1.2
53|48	-0.17	-0.31	0.39	-1.7	-3.1	3.9
53|48	-0.04	-0.24	0.31	-0.4	-2.4	3.1
53|48	0.02	-0.19	0.29	0.2	-1.9	2.9
53|48	-0.12	-0.21	0.39	-1.2	-2.1	3.9
53|48	-0.21	-0.34	0.46	-2.1	-3.4	4.6
53|48	-0.14	-0.43	0.21	-1.4	-4.3	2.1
53|48	-0.07	-0.41	0.29	-0.7	-4.1	2.9
53|48	-0.21	-0.26	0.39	-2.1	-2.6	3.9
53|48	-0.39	-0.19	0.43	-3.9	-1.9	4.3
53|48	-0.12	-0.19	0.19	-1.2	-1.9	1.9
53|48	-0.04	-0.09	0.29	-0.4	-0.9	2.9
53|48	-0.17	0.07	0.63	-1.7	0.7	6.3
53|48	-0.12	0.26	0.46	-1.2	2.6	4.6
53|48	0.02	0.26	0.31	0.2	2.6	3.1
53|48	-0.12	0.17	0.43	-1.2	1.7	4.3
53|48	-0.24	0.04	0.46	-2.4	0.4	4.6
53|48	-0.09	-0.09	0.17	-0.9	-0.9	1.7
53|48	-0.07	-0.14	0.24	-0.7	-1.4	2.4
53|48	-0.31	-0.09	0.53	-3.1	-0.9	5.3
53|48	-0.26	-0.17	0.36	-2.6	-1.7	3.6
53|48	-0.02	-0.24	0.07	-0.2	-2.4	0.7
53|48	-0.04	-0.19	0.17	-0.4	-1.9	1.7
53|48	-0.12	-0.07	0.36	-1.2	-0.7	3.6
53|48	-0.09	0.02	0.26	-0.9	0.2	2.6
53|48	-0.19	0	0.31	-1.9	0	3.1
53|48	-0.17	-0.12	0.21	-1.7	-1.2	2.1
53|48	-0.12	-0.21	0.24	-1.2	-2.1	2.4
53|48	-0.09	-0.02	0.21	-0.9	-0.2	2.1
53|48	-0.07	0.09	0.39	-0.7	0.9	3.9
53|48	-0.12	0.09	0.51	-1.2	0.9	5.1
53|48	-0.17	0.02	0.51	-1.7	0.2	5.1
53|48	-0.17	-0.14	0.29	-1.7	-1.4	2.9
53|48	-0.04	-0.24	0.19	-0.4	-2.4	1.9
53|48	0	-0.14	0.24	0	-1.4	2.4
53|48	-0.21	0	0.34	-2.1	0	3.4
53|48	-0.36	-0.02	0.31	-3.6	-0.2	3.1
53|48	-0.17	-0.14	0.09	-1.7	-1.4	0.9
53|48	-0.02	-0.17	0	-0.2	-1.7	0
53|48	-0.12	-0.02	0.29	-1.2	-0.2	2.9
53|48	-0.09	0.14	0.29	-0.9	1.4	2.9
53|48	-0.04	0.19	0.14	-0.4	1.9	1.4

53|48	-0.07	0.14	0.09	-0.7	1.4	0.9
53|48	-0.24	0.04	0.07	-2.4	0.4	0.7
53|48	-0.12	-0.07	-0.09	-1.2	-0.7	-0.9
53|48	0.02	-0.02	-0.19	0.2	-0.2	-1.9
53|48	-0.07	0.14	0.14	-0.7	1.4	1.4
53|48	-0.14	0.24	0.19	-1.4	2.4	1.9
53|48	-0.07	0.04	-0.04	-0.7	0.4	-0.4
53|48	0.14	-0.12	-0.12	1.4	-1.2	-1.2
53|48	-0.12	-0.07	0.14	-1.2	-0.7	1.4
53|48	-0.19	-0.04	0.26	-1.9	-0.4	2.6
53|48	-0.04	-0.12	-0.02	-0.4	-1.2	-0.2
53|48	-0.04	-0.24	0.04	-0.4	-2.4	0.4
53|48	-0.04	-0.24	0.09	-0.4	-2.4	0.9
53|48	-0.02	-0.26	0.04	-0.2	-2.6	0.4
53|48	-0.09	-0.21	0	-0.9	-2.1	0
53|48	-0.07	-0.19	0.07	-0.7	-1.9	0.7
53|48	-0.09	-0.24	0	-0.9	-2.4	0
53|48	-0.07	-0.31	0	-0.7	-3.1	0
53|48	-0.02	-0.31	-0.04	-0.2	-3.1	-0.4
53|48	-0.04	-0.19	0	-0.4	-1.9	0
53|48	-0.07	-0.14	-0.02	-0.7	-1.4	-0.2
53|48	-0.17	-0.17	0.04	-1.7	-1.7	0.4
53|48	-0.21	-0.19	0.04	-2.1	-1.9	0.4
53|48	-0.09	-0.12	-0.02	-0.9	-1.2	-0.2
53|48	-0.07	0.04	0.07	-0.7	0.4	0.7
53|48	-0.09	0.24	0.12	-0.9	2.4	1.2
53|48	0.07	0.34	0.12	0.7	3.4	1.2
53|48	0.04	0.26	0.12	0.4	2.6	1.2
53|48	-0.09	0.17	0.29	-0.9	1.7	2.9
53|48	-0.14	0.02	0.29	-1.4	0.2	2.9
53|48	-0.07	-0.12	0.21	-0.7	-1.2	2.1
53|48	-0.09	-0.14	0.24	-0.9	-1.4	2.4
53|48	-0.14	-0.09	0.17	-1.4	-0.9	1.7
53|48	-0.12	-0.02	0.07	-1.2	-0.2	0.7
53|48	-0.09	0.04	0.09	-0.9	0.4	0.9
53|48	-0.04	0.07	0.02	-0.4	0.7	0.2
53|48	0	0.04	0	0	0.4	0
53|48	0.04	0	-0.07	0.4	0	-0.7
53|48	0.04	0	-0.09	0.4	0	-0.9
53|48	-0.12	-0.02	0.02	-1.2	-0.2	0.2
53|48	-0.21	-0.04	0.12	-2.1	-0.4	1.2
53|48	-0.14	-0.12	-0.02	-1.4	-1.2	-0.2
53|48	0.04	-0.19	-0.04	0.4	-1.9	-0.4

53|48	0.02	-0.09	0.12	0.2	-0.9	1.2
53|48	-0.07	0.02	0.21	-0.7	0.2	2.1
53|48	-0.04	0.02	0.04	-0.4	0.2	0.4
53|48	-0.09	-0.04	0.02	-0.9	-0.4	0.2
53|48	-0.12	-0.14	0.12	-1.2	-1.4	1.2
53|48	0	-0.12	0	0	-1.2	0
53|48	0.02	-0.02	-0.02	0.2	-0.2	-0.2
53|48	-0.09	0.12	0.04	-0.9	1.2	0.4
53|48	-0.19	0.09	0.07	-1.9	0.9	0.7
53|48	-0.12	0.02	-0.24	-1.2	0.2	-2.4
53|48	0	-0.14	-0.34	0	-1.4	-3.4
53|48	0.07	0.02	-0.36	0.7	0.2	-3.6
53|48	0	0.19	-0.04	0	1.9	-0.4
53|48	-0.12	0.24	-0.02	-1.2	2.4	-0.2
53|48	-0.17	0.07	-0.07	-1.7	0.7	-0.7
53|48	-0.04	-0.09	-0.26	-0.4	-0.9	-2.6
53|48	0.09	-0.14	-0.29	0.9	-1.4	-2.9
53|48	0.02	0.09	0	0.2	0.9	0
53|48	0	0.26	-0.02	0	2.6	-0.2
53|48	0	0.29	-0.04	0	2.9	-0.4
53|48	-0.17	0.12	0.09	-1.7	1.2	0.9
53|48	0.04	-0.04	-0.17	0.4	-0.4	-1.7
53|48	0.41	-0.09	-0.31	4.1	-0.9	-3.1
53|48	0.17	0.12	-0.02	1.7	1.2	-0.2
53|48	-0.26	0.19	0.29	-2.6	1.9	2.9
53|48	-0.21	-0.09	0	-2.1	-0.9	0
53|48	-0.02	-0.48	-0.31	-0.2	-4.8	-3.1
53|48	0.14	-0.61	-0.34	1.4	-6.1	-3.4
53|48	0.34	-0.43	-0.24	3.4	-4.3	-2.4
53|48	0.04	-0.02	0.36	0.4	-0.2	3.6
53|48	-0.34	0.07	0.19	-3.4	0.7	1.9
53|48	-0.21	-0.26	-0.04	-2.1	-2.6	-0.4
53|48	0.09	-0.63	-0.21	0.9	-6.3	-2.1
53|48	0.19	-0.46	-0.46	1.9	-4.6	-4.6
53|48	0.07	-0.02	0.14	0.7	-0.2	1.4
53|48	-0.02	0.17	0.19	-0.2	1.7	1.9
53|48	-0.07	-0.04	0.07	-0.7	-0.4	0.7
53|48	-0.07	-0.31	-0.17	-0.7	-3.1	-1.7
53|48	-0.02	-0.36	-0.21	-0.2	-3.6	-2.1
53|48	-0.07	0	-0.02	-0.7	0	-0.2
53|48	-0.07	0.34	0.12	-0.7	3.4	1.2
53|48	0.02	0.34	0.04	0.2	3.4	0.4
53|48	0.14	0.12	0.02	1.4	1.2	0.2

53|48	0.07	-0.02	0.12	0.7	-0.2	1.2
53|48	-0.07	0	0.14	-0.7	0	1.4
53|48	-0.14	0.09	0.14	-1.4	0.9	1.4
53|48	-0.14	0.04	0.12	-1.4	0.4	1.2
53|48	-0.02	-0.04	0.02	-0.2	-0.4	0.2
53|48	0.07	-0.02	-0.09	0.7	-0.2	-0.9
53|48	0	0.09	0	0	0.9	0
53|48	-0.02	0.19	-0.04	-0.2	1.9	-0.4
53|48	-0.07	0.07	-0.04	-0.7	0.7	-0.4
53|48	0.02	-0.14	-0.26	0.2	-1.4	-2.6
53|48	-0.04	-0.19	-0.31	-0.4	-1.9	-3.1
53|48	-0.07	-0.12	-0.14	-0.7	-1.2	-1.4
53|48	-0.04	0.02	-0.04	-0.4	0.2	-0.4
53|48	-0.07	0.04	-0.04	-0.7	0.4	-0.4
53|48	-0.04	-0.02	-0.09	-0.4	-0.2	-0.9
53|48	0.09	-0.14	-0.17	0.9	-1.4	-1.7
53|48	0.02	-0.07	-0.12	0.2	-0.7	-1.2
53|48	-0.09	0.04	0	-0.9	0.4	0
53|48	-0.12	0.04	0	-1.2	0.4	0
53|48	-0.04	-0.02	-0.12	-0.4	-0.2	-1.2
53|48	0.02	-0.04	-0.12	0.2	-0.4	-1.2
53|48	0	-0.02	0.04	0	-0.2	0.4
53|48	0.07	0.04	-0.17	0.7	0.4	-1.7
53|48	0.02	0.07	-0.14	0.2	0.7	-1.4
53|48	-0.12	0.04	-0.04	-1.2	0.4	-0.4
53|48	-0.14	-0.07	-0.21	-1.4	-0.7	-2.1
53|48	-0.04	-0.14	-0.41	-0.4	-1.4	-4.1
53|48	-0.07	-0.04	-0.26	-0.7	-0.4	-2.6
53|48	0.04	0.02	-0.24	0.4	0.2	-2.4
53|48	0.14	0.07	-0.36	1.4	0.7	-3.6
53|48	-0.02	0.12	-0.14	-0.2	1.2	-1.4
53|48	-0.14	0.02	-0.17	-1.4	0.2	-1.7
53|48	0	-0.07	-0.41	0	-0.7	-4.1
53|48	0	-0.09	-0.36	0	-0.9	-3.6
53|48	0	0	-0.14	0	0	-1.4
53|48	0.07	0.12	-0.14	0.7	1.2	-1.4
53|48	-0.02	0.19	-0.04	-0.2	1.9	-0.4
53|48	0.04	0.02	-0.14	0.4	0.2	-1.4
53|48	0.19	-0.04	-0.14	1.9	-0.4	-1.4
53|48	0.14	-0.07	-0.19	1.4	-0.7	-1.9
53|48	0	-0.04	0.07	0	-0.4	0.7
53|48	0.02	-0.17	-0.14	0.2	-1.7	-1.4
53|48	-0.04	-0.39	-0.09	-0.4	-3.9	-0.9

53|48	-0.14	-0.51	0	-1.4	-5.1	0
53|48	-0.02	-0.58	-0.14	-0.2	-5.8	-1.4
53|48	0	-0.46	-0.09	0	-4.6	-0.9
53|48	-0.04	-0.36	0.17	-0.4	-3.6	1.7
53|48	-0.04	-0.19	0.24	-0.4	-1.9	2.4
53|48	0.04	-0.19	0.04	0.4	-1.9	0.4
53|48	0.19	-0.17	-0.24	1.9	-1.7	-2.4
53|48	0.12	-0.14	-0.02	1.2	-1.4	-0.2
53|48	-0.04	-0.12	-0.04	-0.4	-1.2	-0.4
53|48	-0.14	-0.21	0.07	-1.4	-2.1	0.7
53|48	-0.17	-0.34	-0.02	-1.7	-3.4	-0.2
53|48	-0.12	-0.34	-0.09	-1.2	-3.4	-0.9
53|48	0.12	-0.21	0.02	1.2	-2.1	0.2
53|48	0.04	0.09	0.12	0.4	0.9	1.2
53|48	-0.02	0.26	0.26	-0.2	2.6	2.6
53|48	-0.09	-0.04	0.19	-0.9	-0.4	1.9
53|48	-0.12	-0.04	0.14	-1.2	-0.4	1.4
53|48	-0.17	-0.07	0.17	-1.7	-0.7	1.7
53|48	-0.09	-0.12	0.17	-0.9	-1.2	1.7
53|48	0.02	-0.07	0.07	0.2	-0.7	0.7
53|48	-0.02	-0.07	0.19	-0.2	-0.7	1.9
53|48	-0.21	0.02	0.31	-2.1	0.2	3.1
53|48	-0.12	-0.04	0.12	-1.2	-0.4	1.2
53|48	0.02	-0.09	-0.04	0.2	-0.9	-0.4
53|48	-0.07	-0.02	0.09	-0.7	-0.2	0.9
53|48	-0.12	0.07	0.21	-1.2	0.7	2.1
53|48	0.07	0.09	-0.02	0.7	0.9	-0.2
53|48	-0.04	0.02	0.21	-0.4	0.2	2.1
53|48	-0.31	-0.09	0.51	-3.1	-0.9	5.1
53|48	-0.14	-0.31	-0.04	-1.4	-3.1	-0.4
53|49	-0.04	-0.43	-0.04	-0.4	-4.3	-0.4
53|49	-0.12	-0.36	0.24	-1.2	-3.6	2.4
53|49	0.24	-0.26	0.17	2.4	-2.6	1.7
53|49	-0.02	-0.12	0.29	-0.2	-1.2	2.9
53|49	-0.12	-0.09	0.46	-1.2	-0.9	4.6
53|49	-0.14	-0.17	0.43	-1.4	-1.7	4.3
53|49	0.04	-0.31	0.14	0.4	-3.1	1.4
53|49	0.02	-0.31	0.19	0.2	-3.1	1.9
53|49	-0.04	-0.29	0.26	-0.4	-2.9	2.6
53|49	-0.17	-0.31	0.34	-1.7	-3.1	3.4
53|49	-0.21	-0.31	0.26	-2.1	-3.1	2.6
53|49	-0.17	-0.39	0.31	-1.7	-3.9	3.1
53|49	-0.12	-0.34	0.26	-1.2	-3.4	2.6

53|49	0	-0.17	0.43	0	-1.7	4.3
53|49	0.02	0.12	0.43	0.2	1.2	4.3
53|49	-0.04	0.26	0.51	-0.4	2.6	5.1
53|49	-0.19	0.24	0.56	-1.9	2.4	5.6
53|49	0.02	0.07	0.36	0.2	0.7	3.6
53|49	0.02	0	0.43	0.2	0	4.3
53|49	-0.17	-0.04	0.61	-1.7	-0.4	6.1
53|49	-0.19	-0.04	0.36	-1.9	-0.4	3.6
53|49	-0.12	-0.12	0.24	-1.2	-1.2	2.4
53|49	-0.17	-0.14	0.31	-1.7	-1.4	3.1
53|49	-0.09	-0.07	0.24	-0.9	-0.7	2.4
53|49	0.04	0	0.07	0.4	0	0.7
53|49	-0.07	0.07	0.12	-0.7	0.7	1.2
53|49	-0.14	-0.07	0.19	-1.4	-0.7	1.9
53|49	-0.12	-0.26	0.12	-1.2	-2.6	1.2
53|49	-0.02	-0.39	0.04	-0.2	-3.9	0.4
53|49	-0.09	-0.24	0.21	-0.9	-2.4	2.1
53|49	-0.17	-0.09	0.26	-1.7	-0.9	2.6
53|49	-0.07	-0.07	0.12	-0.7	-0.7	1.2
53|49	0.07	-0.04	0.02	0.7	-0.4	0.2
53|49	-0.17	-0.02	0.36	-1.7	-0.2	3.6
53|49	-0.14	-0.07	0.07	-1.4	-0.7	0.7
53|49	-0.04	-0.12	-0.07	-0.4	-1.2	-0.7
53|49	-0.31	-0.14	0.14	-3.1	-1.4	1.4
53|49	-0.26	-0.26	0.26	-2.6	-2.6	2.6
53|49	0.19	-0.26	-0.31	1.9	-2.6	-3.1
53|49	-0.14	-0.07	0.07	-1.4	-0.7	0.7
53|49	-0.36	0.12	0.34	-3.6	1.2	3.4
53|49	-0.09	0.12	-0.02	-0.9	1.2	-0.2
53|49	-0.02	-0.04	-0.26	-0.2	-0.4	-2.6
53|49	-0.19	-0.07	0.02	-1.9	-0.7	0.2
53|49	-0.07	-0.14	-0.21	-0.7	-1.4	-2.1
53|49	-0.12	0.07	-0.12	-1.2	0.7	-1.2
53|49	-0.29	0.14	0.04	-2.9	1.4	0.4
53|49	-0.09	-0.02	-0.12	-0.9	-0.2	-1.2
53|49	0.19	-0.12	-0.21	1.9	-1.2	-2.1
53|49	-0.02	-0.07	0.14	-0.2	-0.7	1.4
53|49	-0.48	-0.12	0.48	-4.8	-1.2	4.8
53|49	-0.26	-0.29	0.14	-2.6	-2.9	1.4
53|49	0	-0.61	-0.07	0	-6.1	-0.7
53|49	0.04	-0.56	-0.07	0.4	-5.6	-0.7
53|49	-0.12	-0.36	0.04	-1.2	-3.6	0.4
53|49	-0.21	-0.07	0.29	-2.1	-0.7	2.9

53|49	-0.36	-0.07	0.09	-3.6	-0.7	0.9
53|49	-0.04	-0.19	-0.04	-0.4	-1.9	-0.4
53|49	0.19	-0.34	-0.12	1.9	-3.4	-1.2
53|49	0.04	-0.26	0.07	0.4	-2.6	0.7
53|49	-0.19	-0.14	0.31	-1.9	-1.4	3.1
53|49	-0.12	-0.12	0.29	-1.2	-1.2	2.9
53|49	-0.24	-0.31	0.29	-2.4	-3.1	2.9
53|49	-0.17	-0.46	0.12	-1.7	-4.6	1.2
53|49	-0.04	-0.36	0.02	-0.4	-3.6	0.2
53|49	-0.12	0	0.29	-1.2	0	2.9
53|49	-0.17	0.26	0.26	-1.7	2.6	2.6
53|49	-0.02	0.24	0.19	-0.2	2.4	1.9
53|49	0.04	0.12	0.04	0.4	1.2	0.4
53|49	0	0.04	0.17	0	0.4	1.7
53|49	-0.17	0.07	0.26	-1.7	0.7	2.6
53|49	-0.12	0.12	0.19	-1.2	1.2	1.9
53|49	-0.09	0	0.09	-0.9	0	0.9
53|49	-0.14	-0.12	0.19	-1.4	-1.2	1.9
53|49	-0.12	-0.14	0.19	-1.2	-1.4	1.9
53|49	0	-0.07	-0.04	0	-0.7	-0.4
53|49	-0.17	0.02	0.24	-1.7	0.2	2.4
53|49	-0.26	0.04	0.02	-2.6	0.4	0.2
53|49	0	-0.09	-0.24	0	-0.9	-2.4
53|49	0.07	-0.12	-0.21	0.7	-1.2	-2.1
53|49	-0.14	-0.02	0.36	-1.4	-0.2	3.6
53|49	-0.04	0.04	0.21	-0.4	0.4	2.1
53|49	-0.02	0.02	0.21	-0.2	0.2	2.1
53|49	-0.12	-0.04	0.19	-1.2	-0.4	1.9
53|49	-0.07	-0.14	0.07	-0.7	-1.4	0.7
53|49	0	-0.14	0	0	-1.4	0
53|49	-0.09	0	0.09	-0.9	0	0.9
53|49	-0.14	-0.02	0.24	-1.4	-0.2	2.4
53|49	-0.09	-0.07	0.19	-0.9	-0.7	1.9
53|49	0.02	-0.14	-0.07	0.2	-1.4	-0.7
53|49	-0.04	-0.14	-0.07	-0.4	-1.4	-0.7
53|49	-0.19	-0.04	0.07	-1.9	-0.4	0.7
53|49	-0.07	0	-0.04	-0.7	0	-0.4
53|49	0	0	0.02	0	0	0.2
53|49	-0.14	0.04	0.17	-1.4	0.4	1.7
53|49	-0.19	0.04	0.17	-1.9	0.4	1.7
53|49	0.04	0.04	-0.09	0.4	0.4	-0.9
53|49	0.02	0.09	-0.02	0.2	0.9	-0.2
53|49	0	0.14	0.04	0	1.4	0.4

53|49	-0.09	0.19	0.12	-0.9	1.9	1.2
53|49	-0.02	0.17	-0.17	-0.2	1.7	-1.7
53|49	-0.04	0.09	0	-0.4	0.9	0
53|49	-0.14	0	0	-1.4	0	0
53|49	0.07	-0.17	-0.14	0.7	-1.7	-1.4
53|49	0.09	-0.21	-0.21	0.9	-2.1	-2.1
53|49	-0.17	-0.24	0.04	-1.7	-2.4	0.4
53|49	-0.29	-0.26	0.09	-2.9	-2.6	0.9
53|49	-0.07	-0.34	-0.36	-0.7	-3.4	-3.6
53|49	-0.02	-0.36	-0.17	-0.2	-3.6	-1.7
53|49	-0.04	-0.24	0.07	-0.4	-2.4	0.7
53|49	0.02	-0.12	0.07	0.2	-1.2	0.7
53|49	0.04	-0.09	0.02	0.4	-0.9	0.2
53|49	0	-0.14	0.02	0	-1.4	0.2
53|49	-0.09	-0.24	-0.12	-0.9	-2.4	-1.2
53|49	-0.12	-0.31	-0.02	-1.2	-3.1	-0.2
53|49	-0.09	-0.26	0.07	-0.9	-2.6	0.7
53|49	-0.17	-0.17	0.17	-1.7	-1.7	1.7
53|49	-0.24	-0.09	0.21	-2.4	-0.9	2.1
53|49	-0.02	-0.07	-0.04	-0.2	-0.7	-0.4
53|49	0.07	-0.02	0	0.7	-0.2	0
53|49	-0.04	0.14	0.21	-0.4	1.4	2.1
53|49	-0.12	0.21	0.17	-1.2	2.1	1.7
53|49	-0.07	0.14	0.02	-0.7	1.4	0.2
53|49	-0.09	0.02	0.14	-0.9	0.2	1.4
53|49	-0.09	-0.04	0.17	-0.9	-0.4	1.7
53|49	-0.07	-0.12	0.12	-0.7	-1.2	1.2
53|49	-0.04	0	0.12	-0.4	0	1.2
53|49	-0.14	0	0.24	-1.4	0	2.4
53|49	-0.17	-0.07	0.29	-1.7	-0.7	2.9
53|49	-0.09	-0.12	0.07	-0.9	-1.2	0.7
53|49	0	-0.14	-0.02	0	-1.4	-0.2
53|49	-0.04	0.02	0.07	-0.4	0.2	0.7
53|49	-0.09	0.09	0.17	-0.9	0.9	1.7
53|49	-0.04	0.04	0.07	-0.4	0.4	0.7
53|49	-0.04	-0.02	0.07	-0.4	-0.2	0.7
53|49	-0.04	-0.04	0.02	-0.4	-0.4	0.2
53|49	-0.04	0	0.04	-0.4	0	0.4
53|49	-0.02	0	0.09	-0.2	0	0.9
53|49	-0.14	0	0.19	-1.4	0	1.9
53|49	-0.12	-0.04	0.04	-1.2	-0.4	0.4
53|49	-0.04	-0.14	0	-0.4	-1.4	0
53|49	-0.02	-0.17	0.09	-0.2	-1.7	0.9

53|49	0	-0.09	0.12	0	-0.9	1.2
53|49	0	-0.02	0.07	0	-0.2	0.7
53|49	-0.14	-0.04	0.12	-1.4	-0.4	1.2
53|49	-0.21	-0.09	0.14	-2.1	-0.9	1.4
53|49	-0.04	-0.14	-0.17	-0.4	-1.4	-1.7
53|49	-0.02	-0.07	0	-0.2	-0.7	0
53|49	-0.02	0.02	0.07	-0.2	0.2	0.7
53|49	0	0.12	0	0	1.2	0
53|49	-0.04	0.17	-0.04	-0.4	1.7	-0.4
53|49	-0.14	0.04	-0.04	-1.4	0.4	-0.4
53|49	-0.14	0	-0.12	-1.4	0	-1.2
53|49	-0.02	0.02	-0.12	-0.2	0.2	-1.2
53|49	0.12	0.04	-0.19	1.2	0.4	-1.9
53|49	-0.02	0.12	0.04	-0.2	1.2	0.4
53|49	-0.14	0.09	0.12	-1.4	0.9	1.2
53|49	0.09	-0.04	-0.31	0.9	-0.4	-3.1
53|49	0.07	-0.12	-0.34	0.7	-1.2	-3.4
53|49	-0.09	-0.07	0.14	-0.9	-0.7	1.4
53|49	0	-0.04	-0.24	0	-0.4	-2.4
53|49	-0.12	-0.14	-0.26	-1.2	-1.4	-2.6
53|49	-0.21	-0.34	0	-2.1	-3.4	0
53|49	0.04	-0.48	-0.36	0.4	-4.8	-3.6
53|49	0.17	-0.46	-0.26	1.7	-4.6	-2.6
53|49	0.07	-0.24	0.39	0.7	-2.4	3.9
53|49	-0.04	-0.17	0	-0.4	-1.7	0
53|49	0	-0.21	-0.14	0	-2.1	-1.4
53|49	-0.07	-0.31	0.02	-0.7	-3.1	0.2
53|49	-0.04	-0.36	-0.09	-0.4	-3.6	-0.9
53|49	0.14	-0.26	-0.31	1.4	-2.6	-3.1
53|49	0.07	-0.07	-0.02	0.7	-0.7	-0.2
53|49	-0.21	-0.07	-0.09	-2.1	-0.7	-0.9
53|49	-0.12	-0.17	-0.14	-1.2	-1.7	-1.4
53|49	0.02	-0.19	-0.24	0.2	-1.9	-2.4
53|49	-0.07	-0.02	0.04	-0.7	-0.2	0.4
53|49	-0.04	0.17	0.12	-0.4	1.7	1.2
53|49	0.12	0.24	-0.07	1.2	2.4	-0.7
53|49	0	0.19	0.24	0	1.9	2.4
53|49	-0.14	0.12	0.26	-1.4	1.2	2.6
53|49	0	0	-0.09	0	0	-0.9
53|49	-0.04	-0.02	0.04	-0.4	-0.2	0.4
53|49	-0.12	0.04	0.24	-1.2	0.4	2.4
53|49	-0.02	0.02	0.09	-0.2	0.2	0.9
53|49	-0.07	0	0.04	-0.7	0	0.4

53|49	-0.02	-0.04	-0.07	-0.2	-0.4	-0.7
53|49	0	-0.07	-0.12	0	-0.7	-1.2
53|49	0.04	0	-0.21	0.4	0	-2.1
53|49	0	0.07	-0.09	0	0.7	-0.9
53|49	-0.04	0.04	-0.12	-0.4	0.4	-1.2
53|49	-0.09	-0.04	-0.12	-0.9	-0.4	-1.2
53|49	-0.12	-0.17	-0.24	-1.2	-1.7	-2.4
53|49	0	-0.24	-0.21	0	-2.4	-2.1
53|49	0.04	-0.14	-0.19	0.4	-1.4	-1.9
53|49	0	-0.04	-0.17	0	-0.4	-1.7
53|49	-0.09	-0.07	-0.12	-0.9	-0.7	-1.2
53|49	-0.04	-0.12	-0.14	-0.4	-1.2	-1.4
53|49	-0.04	-0.19	-0.19	-0.4	-1.9	-1.9
53|49	0	-0.17	-0.26	0	-1.7	-2.6
53|49	0.04	-0.04	-0.31	0.4	-0.4	-3.1
53|49	0	0	-0.17	0	0	-1.7
53|49	-0.12	0.02	-0.02	-1.2	0.2	-0.2
53|49	-0.12	-0.04	-0.19	-1.2	-0.4	-1.9
53|49	0	-0.07	-0.36	0	-0.7	-3.6
53|49	-0.04	0.04	-0.21	-0.4	0.4	-2.1
53|49	-0.02	0.09	-0.29	-0.2	0.9	-2.9
53|49	0	0.02	-0.19	0	0.2	-1.9
53|49	-0.09	0	-0.09	-0.9	0	-0.9
53|49	-0.07	-0.07	-0.24	-0.7	-0.7	-2.4
53|49	0.02	-0.07	-0.26	0.2	-0.7	-2.6
53|49	0.04	0.07	-0.12	0.4	0.7	-1.2
53|49	-0.07	0.17	-0.02	-0.7	1.7	-0.2
53|49	-0.09	0.04	-0.07	-0.9	0.4	-0.7
53|49	0.09	-0.09	-0.36	0.9	-0.9	-3.6
53|49	0.12	-0.12	-0.39	1.2	-1.2	-3.9
53|49	-0.02	0	-0.12	-0.2	0	-1.2
53|49	-0.07	0	-0.04	-0.7	0	-0.4
53|49	-0.14	-0.14	-0.14	-1.4	-1.4	-1.4
53|49	-0.14	-0.36	-0.19	-1.4	-3.6	-1.9
53|49	0.17	-0.53	-0.31	1.7	-5.3	-3.1
53|49	0.29	-0.39	-0.36	2.9	-3.9	-3.6
53|49	-0.07	-0.12	0.17	-0.7	-1.2	1.7
53|49	-0.12	-0.07	-0.02	-1.2	-0.7	-0.2
53|49	-0.12	-0.34	-0.17	-1.2	-3.4	-1.7
53|49	-0.14	-0.51	-0.36	-1.4	-5.1	-3.6
53|49	0.12	-0.48	-0.43	1.2	-4.8	-4.3
53|49	0.12	-0.26	-0.31	1.2	-2.6	-3.1
53|49	-0.09	-0.04	0.12	-0.9	-0.4	1.2

53|49	-0.07	-0.12	0	-0.7	-1.2	0
53|49	-0.09	-0.29	-0.26	-0.9	-2.9	-2.6
53|49	-0.14	-0.26	-0.24	-1.4	-2.6	-2.4
53|49	0	-0.04	-0.24	0	-0.4	-2.4
53|49	0.02	0.21	-0.12	0.2	2.1	-1.2
53|49	-0.04	0.29	0.12	-0.4	2.9	1.2
53|49	0	0.09	0.07	0	0.9	0.7
53|49	0.07	-0.09	-0.02	0.7	-0.9	-0.2
53|49	-0.07	-0.12	0.07	-0.7	-1.2	0.7
53|49	-0.14	-0.04	0.14	-1.4	-0.4	1.4
53|49	-0.12	0.02	-0.02	-1.2	0.2	-0.2
53|49	-0.07	-0.02	-0.04	-0.7	-0.2	-0.4
53|49	-0.07	-0.04	-0.12	-0.7	-0.4	-1.2
53|49	-0.04	-0.04	-0.14	-0.4	-0.4	-1.4
53|49	-0.04	0.02	-0.21	-0.4	0.2	-2.1
53|49	0	0.04	-0.24	0	0.4	-2.4
53|49	-0.02	-0.02	-0.17	-0.2	-0.2	-1.7
53|49	-0.07	-0.14	-0.19	-0.7	-1.4	-1.9
53|49	-0.02	-0.19	-0.26	-0.2	-1.9	-2.6
53|49	-0.09	-0.14	-0.19	-0.9	-1.4	-1.9
53|49	-0.14	-0.12	0	-1.4	-1.2	0
53|49	0	-0.14	-0.12	0	-1.4	-1.2
53|49	0	-0.19	-0.19	0	-1.9	-1.9
53|49	-0.12	-0.19	-0.07	-1.2	-1.9	-0.7
53|49	-0.09	-0.19	-0.17	-0.9	-1.9	-1.7
53|49	-0.12	-0.12	-0.09	-1.2	-1.2	-0.9
53|49	-0.12	-0.02	-0.02	-1.2	-0.2	-0.2
53|49	0.07	-0.02	-0.12	0.7	-0.2	-1.2
53|49	0.07	0.02	-0.21	0.7	0.2	-2.1
53|49	-0.09	0.07	-0.04	-0.9	0.7	-0.4
53|49	-0.14	-0.02	-0.02	-1.4	-0.2	-0.2
53|49	-0.07	-0.12	-0.21	-0.7	-1.2	-2.1
53|49	-0.07	-0.17	-0.07	-0.7	-1.7	-0.7
53|49	-0.14	-0.14	0.02	-1.4	-1.4	0.2
53|49	-0.02	-0.07	-0.14	-0.2	-0.7	-1.4
53|49	0	0	-0.14	0	0	-1.4
53|49	-0.09	-0.04	-0.07	-0.9	-0.4	-0.7
53|49	-0.07	-0.14	-0.12	-0.7	-1.4	-1.2
53|49	-0.12	-0.17	-0.07	-1.2	-1.7	-0.7
53|49	-0.09	-0.07	-0.12	-0.9	-0.7	-1.2
53|49	-0.19	0.09	0	-1.9	0.9	0
53|49	-0.26	0.09	0.07	-2.6	0.9	0.7
53|49	-0.02	0.02	-0.19	-0.2	0.2	-1.9

53|49	0.07	0.04	-0.31	0.7	0.4	-3.1
53|49	-0.12	0.17	0.21	-1.2	1.7	2.1
53|49	-0.09	0.29	0.36	-0.9	2.9	3.6
53|49	-0.02	0.24	0.04	-0.2	2.4	0.4
53|49	-0.12	0.14	0.12	-1.2	1.4	1.2
53|49	-0.09	0	0.09	-0.9	0	0.9
53|49	0.07	-0.07	-0.09	0.7	-0.7	-0.9
53|49	-0.07	-0.04	0.07	-0.7	-0.4	0.7
53|49	-0.31	-0.12	0.21	-3.1	-1.2	2.1
53|49	-0.21	-0.31	-0.12	-2.1	-3.1	-1.2
53|49	-0.02	-0.48	-0.19	-0.2	-4.8	-1.9
53|49	-0.17	-0.41	0.09	-1.7	-4.1	0.9
53|49	-0.04	-0.24	0.04	-0.4	-2.4	0.4
53|49	0.17	-0.04	-0.07	1.7	-0.4	-0.7
53|49	-0.09	0.02	-0.04	-0.9	0.2	-0.4
53|49	-0.19	-0.07	0.14	-1.9	-0.7	1.4
53|49	0.02	-0.24	-0.12	0.2	-2.4	-1.2
53|49	-0.07	-0.21	-0.14	-0.7	-2.1	-1.4
53|49	-0.29	-0.07	0.41	-2.9	-0.7	4.1
53|49	-0.14	-0.07	0.12	-1.4	-0.7	1.2
53|49	-0.04	-0.07	0.09	-0.4	-0.7	0.9
53|49	-0.12	0	0.36	-1.2	0	3.6
53|49	-0.12	0.12	0.56	-1.2	1.2	5.6
53|49	0.02	0.21	0.31	0.2	2.1	3.1
53|49	-0.02	0.26	0.43	-0.2	2.6	4.3
53|49	-0.14	0.24	0.41	-1.4	2.4	4.1
53|49	-0.04	0.07	0.21	-0.4	0.7	2.1
53|49	-0.02	0	0.14	-0.2	0	1.4
53|49	-0.19	0.02	0.31	-1.9	0.2	3.1
53|49	-0.19	-0.02	0.26	-1.9	-0.2	2.6
53|49	-0.07	-0.07	0	-0.7	-0.7	0
53|49	-0.07	-0.07	0.02	-0.7	-0.7	0.2
53|49	-0.17	0.02	0.12	-1.7	0.2	1.2
53|49	-0.12	0.09	0.09	-1.2	0.9	0.9
53|49	-0.12	0.12	0.26	-1.2	1.2	2.6
53|49	-0.02	0.07	0.14	-0.2	0.7	1.4
53|49	0.02	0.04	0.12	0.2	0.4	1.2
53|49	-0.07	0	0.34	-0.7	0	3.4
53|49	-0.04	0.04	0.19	-0.4	0.4	1.9
53|49	-0.09	0.09	0.19	-0.9	0.9	1.9
53|49	-0.19	0.09	0.48	-1.9	0.9	4.8
53|49	-0.02	0	0.21	-0.2	0	2.1
53|50	0.09	0	0.07	0.9	0	0.7

53|50	-0.12	0.09	0.34	-1.2	0.9	3.4
53|50	-0.21	0.14	0.31	-2.1	1.4	3.1
53|50	-0.14	0	-0.07	-1.4	0	-0.7
53|50	-0.09	-0.12	0	-0.9	-1.2	0
53|50	-0.07	-0.14	0.04	-0.7	-1.4	0.4
53|50	-0.04	0	-0.02	-0.4	0	-0.2
53|50	-0.02	0.12	0	-0.2	1.2	0
53|50	-0.07	0.14	0.09	-0.7	1.4	0.9
53|50	-0.17	0.04	0.19	-1.7	0.4	1.9
53|50	-0.09	0.02	-0.07	-0.9	0.2	-0.7
53|50	0	0.04	-0.17	0	0.4	-1.7
53|50	0	0.12	-0.02	0	1.2	-0.2
53|50	-0.12	0.26	0.17	-1.2	2.6	1.7
53|50	0.07	0.21	-0.02	0.7	2.1	-0.2
53|50	0.07	0.14	0.02	0.7	1.4	0.2
53|50	-0.04	0.07	0.04	-0.4	0.7	0.4
53|50	-0.14	0.04	0.09	-1.4	0.4	0.9
53|50	-0.09	-0.07	-0.09	-0.9	-0.7	-0.9
53|50	0.02	-0.24	0	0.2	-2.4	0
53|50	0	-0.31	0	0	-3.1	0
53|50	-0.09	-0.24	0.07	-0.9	-2.4	0.7
53|50	-0.09	-0.14	0.07	-0.9	-1.4	0.7
53|50	-0.02	-0.09	-0.07	-0.2	-0.9	-0.7
53|50	-0.09	-0.17	0	-0.9	-1.7	0
53|50	-0.04	-0.24	-0.09	-0.4	-2.4	-0.9
53|50	0.07	-0.24	-0.26	0.7	-2.4	-2.6
53|50	0.02	-0.14	-0.02	0.2	-1.4	-0.2
53|50	-0.17	-0.07	0.19	-1.7	-0.7	1.9
53|50	-0.21	-0.17	0.19	-2.1	-1.7	1.9
53|50	-0.04	-0.24	-0.14	-0.4	-2.4	-1.4
53|50	0	-0.14	-0.17	0	-1.4	-1.7
53|50	-0.19	0.12	0.09	-1.9	1.2	0.9
53|50	-0.12	0.34	0.19	-1.2	3.4	1.9
53|50	0.17	0.34	-0.02	1.7	3.4	-0.2
53|50	0	0.29	0.31	0	2.9	3.1
53|50	-0.21	0.21	0.43	-2.1	2.1	4.3
53|50	0.07	0.02	0.07	0.7	0.2	0.7
53|50	0.09	-0.07	0.09	0.9	-0.7	0.9
53|50	-0.31	0	0.53	-3.1	0	5.3
53|50	-0.17	-0.07	0.34	-1.7	-0.7	3.4
53|50	0.07	-0.14	-0.07	0.7	-1.4	-0.7
53|50	-0.21	-0.04	0.26	-2.1	-0.4	2.6
53|50	-0.21	0	0.19	-2.1	0	1.9

53|50	0.17	-0.04	-0.12	1.7	-0.4	-1.2
53|50	0.02	0.04	-0.07	0.2	0.4	-0.7
53|50	-0.29	0.09	0.31	-2.9	0.9	3.1
53|50	-0.12	0.02	-0.04	-1.2	0.2	-0.4
53|50	0.07	-0.09	-0.09	0.7	-0.9	-0.9
53|50	0	-0.07	0.26	0	-0.7	2.6
53|50	-0.02	0.04	0.26	-0.2	0.4	2.6
53|50	-0.07	0.12	0.24	-0.7	1.2	2.4
53|50	-0.17	0.07	0.19	-1.7	0.7	1.9
53|50	-0.02	-0.09	0.07	-0.2	-0.9	0.7
53|50	0.04	-0.17	-0.07	0.4	-1.7	-0.7
53|50	-0.07	-0.04	0.17	-0.7	-0.4	1.7
53|50	-0.14	0.04	0.29	-1.4	0.4	2.9
53|50	-0.07	0.04	0.04	-0.7	0.4	0.4
53|50	-0.12	-0.02	0.17	-1.2	-0.2	1.7
53|50	-0.12	-0.09	-0.02	-1.2	-0.9	-0.2
53|50	0.02	-0.04	-0.09	0.2	-0.4	-0.9
53|50	-0.04	0.09	0.07	-0.4	0.9	0.7
53|50	-0.21	0.14	0.17	-2.1	1.4	1.7
53|50	-0.09	0.02	-0.02	-0.9	0.2	-0.2
53|50	0.04	-0.07	-0.19	0.4	-0.7	-1.9
53|50	-0.02	-0.04	-0.14	-0.2	-0.4	-1.4
53|50	-0.07	0.09	-0.04	-0.7	0.9	-0.4
53|50	-0.04	0.17	-0.07	-0.4	1.7	-0.7
53|50	-0.04	0.09	-0.14	-0.4	0.9	-1.4
53|50	-0.09	-0.04	-0.07	-0.9	-0.4	-0.7
53|50	0.09	-0.09	-0.17	0.9	-0.9	-1.7
53|50	0.09	0	-0.21	0.9	0	-2.1
53|50	-0.07	0.07	0.07	-0.7	0.7	0.7
53|50	-0.04	0.02	-0.04	-0.4	0.2	-0.4
53|50	-0.07	-0.14	0.04	-0.7	-1.4	0.4
53|50	-0.09	-0.29	0.09	-0.9	-2.9	0.9
53|50	0.04	-0.36	-0.07	0.4	-3.6	-0.7
53|50	0.17	-0.31	-0.29	1.7	-3.1	-2.9
53|50	-0.17	-0.14	0.24	-1.7	-1.4	2.4
53|50	-0.21	-0.17	0.04	-2.1	-1.7	0.4
53|50	-0.07	-0.31	-0.24	-0.7	-3.1	-2.4
53|50	0.09	-0.39	-0.21	0.9	-3.9	-2.1
53|50	0.04	-0.26	-0.19	0.4	-2.6	-1.9
53|50	0.02	-0.09	-0.07	0.2	-0.9	-0.7
53|50	0	-0.07	-0.02	0	-0.7	-0.2
53|50	-0.07	-0.19	-0.09	-0.7	-1.9	-0.9
53|50	-0.14	-0.26	-0.14	-1.4	-2.6	-1.4

53|50	-0.12	-0.19	-0.21	-1.2	-1.9	-2.1
53|50	-0.07	0.02	-0.12	-0.7	0.2	-1.2
53|50	0.04	0.17	-0.07	0.4	1.7	-0.7
53|50	0.07	0.19	0.12	0.7	1.9	1.2
53|50	-0.04	0.14	0.21	-0.4	1.4	2.1
53|50	0	0	0	0	0	0
53|50	0.02	-0.04	0.02	0.2	-0.4	0.2
53|50	-0.17	0	0.24	-1.7	0	2.4
53|50	-0.02	0	0.02	-0.2	0	0.2
53|50	0.02	-0.04	-0.04	0.2	-0.4	-0.4
53|50	-0.07	-0.07	0.09	-0.7	-0.7	0.9
53|50	-0.12	-0.07	0.02	-1.2	-0.7	0.2
53|50	-0.02	-0.07	-0.09	-0.2	-0.7	-0.9
53|50	-0.02	-0.07	-0.14	-0.2	-0.7	-1.4
53|50	-0.07	-0.07	-0.07	-0.7	-0.7	-0.7
53|50	-0.04	-0.07	-0.07	-0.4	-0.7	-0.7
53|50	0	-0.04	-0.12	0	-0.4	-1.2
53|50	0	0	-0.07	0	0	-0.7
53|50	-0.07	-0.02	-0.04	-0.7	-0.2	-0.4
53|50	0	-0.12	-0.14	0	-1.2	-1.4
53|50	0.02	-0.19	-0.07	0.2	-1.9	-0.7
53|50	-0.12	-0.19	0	-1.2	-1.9	0
53|50	-0.12	-0.17	-0.02	-1.2	-1.7	-0.2
53|50	-0.07	-0.09	-0.21	-0.7	-0.9	-2.1
53|50	-0.04	-0.09	-0.17	-0.4	-0.9	-1.7
53|50	0.02	-0.07	-0.12	0.2	-0.7	-1.2
53|50	0.12	0	-0.21	1.2	0	-2.1
53|50	0.02	0.04	-0.07	0.2	0.4	-0.7
53|50	-0.17	0.02	-0.07	-1.7	0.2	-0.7
53|50	-0.12	-0.07	-0.21	-1.2	-0.7	-2.1
53|50	-0.07	-0.17	-0.31	-0.7	-1.7	-3.1
53|50	-0.04	-0.12	-0.34	-0.4	-1.2	-3.4
53|50	-0.02	-0.04	-0.26	-0.2	-0.4	-2.6
53|50	0	0.02	-0.19	0	0.2	-1.9
53|50	-0.09	0.04	-0.07	-0.9	0.4	-0.7
53|50	-0.12	-0.14	-0.17	-1.2	-1.4	-1.7
53|50	-0.04	-0.24	-0.39	-0.4	-2.4	-3.9
53|50	0	-0.21	-0.36	0	-2.1	-3.6
53|50	-0.12	-0.02	-0.17	-1.2	-0.2	-1.7
53|50	-0.17	-0.02	-0.12	-1.7	-0.2	-1.2
53|50	0.02	-0.07	-0.26	0.2	-0.7	-2.6
53|50	0.07	-0.12	-0.17	0.7	-1.2	-1.7
53|50	0	-0.12	-0.07	0	-1.2	-0.7

53|50	0.04	-0.07	-0.17	0.4	-0.7	-1.7
53|50	0	-0.19	-0.29	0	-1.9	-2.9
53|50	-0.17	-0.39	-0.17	-1.7	-3.9	-1.7
53|50	-0.17	-0.48	-0.31	-1.7	-4.8	-3.1
53|50	-0.02	-0.46	-0.39	-0.2	-4.6	-3.9
53|50	-0.07	-0.43	-0.26	-0.7	-4.3	-2.6
53|50	-0.07	-0.34	-0.09	-0.7	-3.4	-0.9
53|50	-0.09	-0.31	-0.24	-0.9	-3.1	-2.4
53|50	0.02	-0.39	-0.24	0.2	-3.9	-2.4
53|50	0.02	-0.41	-0.29	0.2	-4.1	-2.9
53|50	-0.02	-0.41	-0.31	-0.2	-4.1	-3.1
53|50	-0.04	-0.34	-0.24	-0.4	-3.4	-2.4
53|50	-0.09	-0.26	-0.17	-0.9	-2.6	-1.7
53|50	-0.09	-0.21	-0.26	-0.9	-2.1	-2.6
53|50	-0.12	-0.19	-0.31	-1.2	-1.9	-3.1
53|50	0.04	-0.12	-0.24	0.4	-1.2	-2.4
53|50	0.12	0	-0.14	1.2	0	-1.4
53|50	0.02	0.09	0.12	0.2	0.9	1.2
53|50	-0.04	0.12	0.21	-0.4	1.2	2.1
53|50	-0.07	0	0.09	-0.7	0	0.9
53|50	-0.07	-0.09	0	-0.7	-0.9	0
53|50	-0.04	-0.21	-0.02	-0.4	-2.1	-0.2
53|50	-0.02	-0.17	-0.07	-0.2	-1.7	-0.7
53|50	-0.07	-0.07	0.02	-0.7	-0.7	0.2
53|50	-0.12	-0.04	0.02	-1.2	-0.4	0.2
53|50	-0.09	-0.04	-0.09	-0.9	-0.4	-0.9
53|50	-0.07	-0.07	-0.12	-0.7	-0.7	-1.2
53|50	0.02	-0.07	-0.26	0.2	-0.7	-2.6
53|50	0.04	-0.02	-0.21	0.4	-0.2	-2.1
53|50	-0.02	0	-0.07	-0.2	0	-0.7
53|50	-0.07	-0.07	-0.09	-0.7	-0.7	-0.9
53|50	-0.09	-0.21	-0.14	-0.9	-2.1	-1.4
53|50	-0.17	-0.29	-0.17	-1.7	-2.9	-1.7
53|50	-0.17	-0.34	-0.21	-1.7	-3.4	-2.1
53|50	-0.04	-0.21	-0.26	-0.4	-2.1	-2.6
53|50	-0.04	-0.12	-0.02	-0.4	-1.2	-0.2
53|50	-0.02	0	0	-0.2	0	0
53|50	0	0.02	0.02	0	0.2	0.2
53|50	-0.02	0	0.04	-0.2	0	0.4
53|50	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|50	0.02	-0.14	-0.17	0.2	-1.4	-1.7
53|50	-0.07	-0.12	-0.02	-0.7	-1.2	-0.2
53|50	-0.17	-0.12	-0.02	-1.7	-1.2	-0.2

53|50	-0.07	-0.09	-0.09	-0.7	-0.9	-0.9
53|50	-0.12	-0.04	-0.04	-1.2	-0.4	-0.4
53|50	-0.09	-0.07	-0.02	-0.9	-0.7	-0.2
53|50	0.04	-0.07	-0.21	0.4	-0.7	-2.1
53|50	-0.02	-0.02	-0.12	-0.2	-0.2	-1.2
53|50	-0.09	-0.07	-0.07	-0.9	-0.7	-0.7
53|50	-0.04	-0.17	-0.04	-0.4	-1.7	-0.4
53|50	-0.09	-0.17	-0.09	-0.9	-1.7	-0.9
53|50	-0.17	-0.14	0.04	-1.7	-1.4	0.4
53|50	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|50	0.12	0	-0.19	1.2	0	-1.9
53|50	-0.14	0.09	0.17	-1.4	0.9	1.7
53|50	-0.07	0	-0.12	-0.7	0	-1.2
53|50	0.29	-0.14	-0.39	2.9	-1.4	-3.9
53|50	0.09	-0.12	-0.04	0.9	-1.2	-0.4
53|50	-0.21	-0.07	0.36	-2.1	-0.7	3.6
53|50	-0.19	-0.24	0.17	-1.9	-2.4	1.7
53|50	-0.09	-0.51	-0.17	-0.9	-5.1	-1.7
53|50	-0.19	-0.7	0.14	-1.9	-7	1.4
53|50	0.02	-0.7	-0.14	0.2	-7	-1.4
53|50	0.12	-0.46	-0.04	1.2	-4.6	-0.4
53|50	-0.09	-0.09	0.24	-0.9	-0.9	2.4
53|50	-0.21	0	0.17	-2.1	0	1.7
53|50	0.04	-0.17	-0.24	0.4	-1.7	-2.4
53|50	0.17	-0.36	-0.46	1.7	-3.6	-4.6
53|50	0	-0.36	0.02	0	-3.6	0.2
53|50	-0.07	-0.19	-0.02	-0.7	-1.9	-0.2
53|50	-0.07	-0.29	-0.04	-0.7	-2.9	-0.4
53|50	-0.29	-0.36	0.12	-2.9	-3.6	1.2
53|50	-0.14	-0.41	-0.04	-1.4	-4.1	-0.4
53|50	0	-0.19	-0.09	0	-1.9	-0.9
53|50	-0.12	0.17	0.14	-1.2	1.7	1.4
53|50	0	0.39	0.26	0	3.9	2.6
53|50	0.09	0.36	0.19	0.9	3.6	1.9
53|50	-0.07	0.17	0.34	-0.7	1.7	3.4
53|50	-0.14	-0.04	0.26	-1.4	-0.4	2.6
53|50	-0.12	-0.04	0.21	-1.2	-0.4	2.1
53|50	-0.12	-0.07	0.26	-1.2	-0.7	2.6
53|50	-0.07	0	0.17	-0.7	0	1.7
53|50	-0.02	0.02	0.09	-0.2	0.2	0.9
53|51	-0.17	-0.53	0	-1.7	-5.3	0
53|51	-0.21	-0.48	-0.02	-2.1	-4.8	-0.2
53|51	-0.09	-0.34	-0.04	-0.9	-3.4	-0.4

53|51	-0.02	-0.12	-0.14	-0.2	-1.2	-1.4
53|51	-0.09	0.02	0.02	-0.9	0.2	0.2
53|51	-0.04	0.02	0	-0.4	0.2	0
53|51	0	-0.12	-0.07	0	-1.2	-0.7
53|51	-0.12	-0.24	0.12	-1.2	-2.4	1.2
53|51	-0.17	-0.21	0.21	-1.7	-2.1	2.1
53|51	-0.04	-0.21	0.07	-0.4	-2.1	0.7
53|51	0	-0.04	0.07	0	-0.4	0.7
53|51	-0.07	0.09	0.24	-0.7	0.9	2.4
53|51	-0.04	0.17	0.02	-0.4	1.7	0.2
53|51	-0.02	0.12	-0.04	-0.2	1.2	-0.4
53|51	-0.02	-0.02	-0.19	-0.2	-0.2	-1.9
53|51	-0.04	-0.09	-0.17	-0.4	-0.9	-1.7
53|51	-0.14	-0.12	-0.02	-1.4	-1.2	-0.2
53|51	-0.17	-0.14	-0.26	-1.7	-1.4	-2.6
53|51	-0.02	-0.17	-0.07	-0.2	-1.7	-0.7
53|51	-0.04	-0.12	0.04	-0.4	-1.2	0.4
53|51	-0.17	-0.07	0.09	-1.7	-0.7	0.9
53|51	-0.02	-0.12	-0.02	-0.2	-1.2	-0.2
53|51	0.04	-0.09	-0.12	0.4	-0.9	-1.2
53|51	-0.14	-0.12	0.12	-1.4	-1.2	1.2
53|51	-0.19	-0.09	0.14	-1.9	-0.9	1.4
53|51	0	-0.07	-0.12	0	-0.7	-1.2
53|51	0	0	0.07	0	0	0.7
53|51	-0.17	0.07	0.24	-1.7	0.7	2.4
53|51	-0.12	0.02	0.17	-1.2	0.2	1.7
53|51	0.12	-0.07	0	1.2	-0.7	0
53|51	0.24	-0.12	-0.14	2.4	-1.2	-1.4
53|51	-0.07	-0.07	0.26	-0.7	-0.7	2.6
53|51	-0.26	-0.04	0.07	-2.6	-0.4	0.7
53|51	-0.19	-0.26	-0.21	-1.9	-2.6	-2.1
53|51	-0.07	-0.53	-0.21	-0.7	-5.3	-2.1
53|51	-0.07	-0.58	-0.07	-0.7	-5.8	-0.7
53|51	0	-0.48	-0.09	0	-4.8	-0.9
53|51	0.04	-0.31	0.12	0.4	-3.1	1.2
53|51	0.09	-0.21	0.34	0.9	-2.1	3.4
53|51	-0.07	-0.24	0.26	-0.7	-2.4	2.6
53|51	-0.02	-0.34	0.02	-0.2	-3.4	0.2
53|51	0	-0.31	-0.04	0	-3.1	-0.4
53|51	-0.07	-0.19	0.09	-0.7	-1.9	0.9
53|51	-0.17	-0.14	0.14	-1.7	-1.4	1.4
53|51	-0.14	-0.17	-0.09	-1.4	-1.7	-0.9
53|51	-0.14	-0.21	-0.02	-1.4	-2.1	-0.2

53|51	-0.12	-0.17	0	-1.2	-1.7	0
53|51	-0.07	0	0.04	-0.7	0	0.4
53|51	-0.07	0.14	0.12	-0.7	1.4	1.2
53|51	0.07	0.19	0.09	0.7	1.9	0.9
53|51	0.07	0.21	0.09	0.7	2.1	0.9
53|51	-0.12	0.14	0.14	-1.2	1.4	1.4
53|51	-0.14	0.02	0.04	-1.4	0.2	0.4
53|51	-0.07	-0.07	-0.07	-0.7	-0.7	-0.7
53|51	-0.14	-0.14	0	-1.4	-1.4	0
53|51	-0.17	-0.12	-0.02	-1.7	-1.2	-0.2
53|51	-0.09	-0.12	-0.07	-0.9	-1.2	-0.7
53|51	-0.09	-0.04	-0.09	-0.9	-0.4	-0.9
53|51	-0.09	-0.04	-0.04	-0.9	-0.4	-0.4
53|51	-0.02	-0.04	-0.09	-0.2	-0.4	-0.9
53|51	-0.02	-0.02	-0.12	-0.2	-0.2	-1.2
53|51	-0.17	0	0.07	-1.7	0	0.7
53|51	-0.14	0	-0.09	-1.4	0	-0.9
53|51	-0.04	-0.07	-0.21	-0.4	-0.7	-2.1
53|51	-0.07	-0.09	-0.14	-0.7	-0.9	-1.4
53|51	-0.07	-0.04	0.02	-0.7	-0.4	0.2
53|51	-0.24	-0.04	-0.09	-2.4	-0.4	-0.9
53|51	-0.02	-0.09	-0.19	-0.2	-0.9	-1.9
53|51	0	-0.19	-0.24	0	-1.9	-2.4
53|51	-0.14	-0.17	-0.17	-1.4	-1.7	-1.7
53|51	-0.12	-0.12	-0.24	-1.2	-1.2	-2.4
53|51	-0.09	-0.07	-0.19	-0.9	-0.7	-1.9
53|51	-0.14	-0.09	-0.02	-1.4	-0.9	-0.2
53|51	-0.09	-0.07	-0.09	-0.9	-0.7	-0.9
53|51	0.07	-0.12	-0.14	0.7	-1.2	-1.4
53|51	-0.04	-0.02	0.09	-0.4	-0.2	0.9
53|51	-0.17	0.02	0.21	-1.7	0.2	2.1
53|51	-0.14	-0.02	0.07	-1.4	-0.2	0.7
53|51	-0.14	-0.12	0.07	-1.4	-1.2	0.7
53|51	-0.12	-0.12	0.07	-1.2	-1.2	0.7
53|51	-0.02	0	-0.02	-0.2	0	-0.2
53|51	-0.02	0.17	0	-0.2	1.7	0
53|51	-0.12	0.24	0.07	-1.2	2.4	0.7
53|51	-0.17	0.14	0.04	-1.7	1.4	0.4
53|51	-0.04	-0.04	-0.12	-0.4	-0.4	-1.2
53|51	0.26	-0.12	-0.19	2.6	-1.2	-1.9
53|51	0.21	0.02	-0.09	2.1	0.2	-0.9
53|51	-0.21	0.19	0.21	-2.1	1.9	2.1
53|51	-0.43	0.07	0.19	-4.3	0.7	1.9

53|51	-0.26	-0.34	-0.29	-2.6	-3.4	-2.9
53|51	0.02	-0.73	-0.07	0.2	-7.3	-0.7
53|51	0.41	-0.73	-0.19	4.1	-7.3	-1.9
53|51	0.19	-0.31	0.31	1.9	-3.1	3.1
53|51	-0.31	0.07	0.46	-3.1	0.7	4.6
53|51	-0.48	-0.14	0.36	-4.8	-1.4	3.6
53|51	-0.07	-0.51	-0.36	-0.7	-5.1	-3.6
53|51	0.17	-0.58	-0.51	1.7	-5.8	-5.1
53|51	0.12	-0.34	0.02	1.2	-3.4	0.2
53|51	-0.02	0.14	0.34	-0.2	1.4	3.4
53|51	-0.09	0.07	0.29	-0.9	0.7	2.9
53|51	-0.17	-0.17	0	-1.7	-1.7	0
53|51	-0.36	-0.41	0.14	-3.6	-4.1	1.4
53|51	0.04	-0.41	0.12	0.4	-4.1	1.2
53|51	0.24	0.12	-0.41	2.4	1.2	-4.1
53|51	-0.12	0.48	0.34	-1.2	4.8	3.4
53|51	-0.07	0.41	0.9	-0.7	4.1	9
53|51	0.17	0	-0.04	1.7	0	-0.4
53|51	-0.12	-0.14	0.24	-1.2	-1.4	2.4
53|51	-0.39	-0.12	0.39	-3.9	-1.2	3.9
53|51	-0.12	-0.04	-0.24	-1.2	-0.4	-2.4
53|51	-0.09	0	-0.17	-0.9	0	-1.7
53|51	-0.19	0.02	0.09	-1.9	0.2	0.9
53|51	-0.04	0.04	-0.02	-0.4	0.4	-0.2
53|51	0	0.12	-0.14	0	1.2	-1.4
53|51	-0.14	0.14	0.21	-1.4	1.4	2.1
53|51	-0.19	0.07	0.07	-1.9	0.7	0.7
53|51	-0.04	-0.07	-0.17	-0.4	-0.7	-1.7
53|51	0.02	-0.17	-0.17	0.2	-1.7	-1.7
53|51	-0.07	-0.02	0	-0.7	-0.2	0
53|51	-0.07	0.12	0.14	-0.7	1.2	1.4
53|51	-0.12	0.19	0.14	-1.2	1.9	1.4
53|51	-0.12	0	-0.02	-1.2	0	-0.2
53|51	-0.02	-0.14	-0.21	-0.2	-1.4	-2.1
53|51	-0.04	-0.21	-0.17	-0.4	-2.1	-1.7
53|51	-0.14	-0.07	0	-1.4	-0.7	0
53|51	-0.14	0	0.02	-1.4	0	0.2
53|51	-0.04	0.02	-0.14	-0.4	0.2	-1.4
53|51	-0.12	0	-0.09	-1.2	0	-0.9
53|51	-0.02	-0.04	-0.14	-0.2	-0.4	-1.4
53|51	-0.02	-0.02	-0.04	-0.2	-0.2	-0.4
53|51	-0.09	-0.02	-0.02	-0.9	-0.2	-0.2
53|51	-0.09	-0.07	-0.07	-0.9	-0.7	-0.7

53|51	-0.14	-0.12	-0.02	-1.4	-1.2	-0.2
53|51	-0.21	-0.09	0.12	-2.1	-0.9	1.2
53|51	-0.09	-0.02	0.04	-0.9	-0.2	0.4
53|51	0.07	0.09	0.12	0.7	0.9	1.2
53|51	0	0.21	0.17	0	2.1	1.7
53|51	-0.14	0.31	0.26	-1.4	3.1	2.6
53|51	-0.07	0.17	0.07	-0.7	1.7	0.7
53|51	0.02	0.02	-0.21	0.2	0.2	-2.1
53|51	-0.09	-0.02	-0.04	-0.9	-0.2	-0.4
53|51	-0.07	-0.02	-0.14	-0.7	-0.2	-1.4
53|51	0.02	-0.12	-0.19	0.2	-1.2	-1.9
53|51	-0.17	-0.12	0.02	-1.7	-1.2	0.2
53|51	-0.26	-0.21	0.14	-2.6	-2.1	1.4
53|51	-0.04	-0.31	-0.09	-0.4	-3.1	-0.9
53|51	0.02	-0.29	-0.09	0.2	-2.9	-0.9
53|51	-0.07	-0.19	0.24	-0.7	-1.9	2.4
53|51	-0.04	-0.12	0.26	-0.4	-1.2	2.6
53|51	0.02	-0.09	-0.07	0.2	-0.9	-0.7
53|51	-0.04	-0.14	0.07	-0.4	-1.4	0.7
53|51	-0.17	-0.17	0.24	-1.7	-1.7	2.4
53|51	-0.09	-0.24	-0.02	-0.9	-2.4	-0.2
53|51	-0.12	-0.19	0.19	-1.2	-1.9	1.9
53|51	-0.26	-0.14	0.36	-2.6	-1.4	3.6
53|51	-0.21	-0.02	0.34	-2.1	-0.2	3.4
53|51	0.02	0	0.12	0.2	0	1.2
53|51	0	0.07	0.34	0	0.7	3.4
53|51	-0.12	0.19	0.46	-1.2	1.9	4.6
53|51	0	0.21	0.29	0	2.1	2.9
53|51	-0.02	0.14	0.21	-0.2	1.4	2.1
53|51	-0.17	0.07	0.36	-1.7	0.7	3.6
53|51	-0.09	-0.02	0.29	-0.9	-0.2	2.9
53|51	-0.02	-0.04	0.07	-0.2	-0.4	0.7
53|51	-0.14	0	0.26	-1.4	0	2.6
53|51	-0.17	0	0.21	-1.7	0	2.1
53|51	-0.09	-0.02	-0.04	-0.9	-0.2	-0.4
53|51	-0.04	-0.04	-0.07	-0.4	-0.4	-0.7
53|51	-0.09	-0.02	0.12	-0.9	-0.2	1.2
53|51	-0.09	0.02	0	-0.9	0.2	0
53|51	-0.07	0.04	0.02	-0.7	0.4	0.2
53|51	-0.09	0.02	0.09	-0.9	0.2	0.9
53|51	-0.07	-0.04	-0.09	-0.7	-0.4	-0.9
53|51	-0.04	-0.04	0.02	-0.4	-0.4	0.2
53|51	-0.09	0	-0.02	-0.9	0	-0.2

53|51	-0.07	-0.02	-0.12	-0.7	-0.2	-1.2
53|51	-0.07	-0.04	-0.04	-0.7	-0.4	-0.4
53|51	-0.14	-0.07	-0.04	-1.4	-0.7	-0.4
53|51	0	-0.12	-0.21	0	-1.2	-2.1
53|51	0.07	0	-0.31	0.7	0	-3.1
53|51	-0.07	0.04	-0.09	-0.7	0.4	-0.9
53|51	-0.21	0.04	-0.02	-2.1	0.4	-0.2
53|51	-0.12	-0.02	-0.21	-1.2	-0.2	-2.1
53|51	-0.04	-0.09	-0.21	-0.4	-0.9	-2.1
53|51	-0.12	-0.09	-0.02	-1.2	-0.9	-0.2
53|51	-0.07	-0.04	0.02	-0.7	-0.4	0.2
53|51	-0.02	0.04	0.02	-0.2	0.4	0.2
53|51	-0.09	0.07	0.14	-0.9	0.7	1.4
53|51	-0.14	0.04	0.14	-1.4	0.4	1.4
53|51	0.02	0	-0.04	0.2	0	-0.4
53|51	0.02	0	-0.09	0.2	0	-0.9
53|51	-0.09	0.09	0.17	-0.9	0.9	1.7
53|51	-0.09	0.12	0.17	-0.9	1.2	1.7
53|51	-0.02	0.04	-0.04	-0.2	0.4	-0.4
53|51	-0.02	-0.07	-0.09	-0.2	-0.7	-0.9
53|51	-0.12	-0.17	0	-1.2	-1.7	0
53|51	0	-0.19	-0.14	0	-1.9	-1.4
53|51	-0.12	-0.19	0	-1.2	-1.9	0
53|51	-0.17	-0.24	0.02	-1.7	-2.4	0.2
53|51	-0.07	-0.31	-0.04	-0.7	-3.1	-0.4
53|51	0.07	-0.29	0.02	0.7	-2.9	0.2
53|51	-0.02	-0.14	0.07	-0.2	-1.4	0.7
53|51	-0.04	-0.04	-0.07	-0.4	-0.4	-0.7
53|51	-0.07	-0.09	0.12	-0.7	-0.9	1.2
53|51	-0.14	-0.24	0.14	-1.4	-2.4	1.4
53|51	-0.07	-0.34	-0.07	-0.7	-3.4	-0.7
53|51	0.04	-0.34	-0.07	0.4	-3.4	-0.7
53|51	-0.12	-0.14	0.19	-1.2	-1.4	1.9
53|51	-0.17	0.02	0.19	-1.7	0.2	1.9
53|51	-0.12	0.09	0.17	-1.2	0.9	1.7
53|51	-0.09	0.04	0.19	-0.9	0.4	1.9
53|51	-0.02	0.04	0.21	-0.2	0.4	2.1
53|51	0.02	0.12	0.31	0.2	1.2	3.1
53|51	-0.02	0.07	0.21	-0.2	0.7	2.1
53|51	-0.12	0.17	0.39	-1.2	1.7	3.9
53|51	-0.14	-0.12	0.31	-1.4	-1.2	3.1
53|51	-0.17	-0.19	0.17	-1.7	-1.9	1.7
53|51	-0.14	-0.19	0.09	-1.4	-1.9	0.9

53|51	-0.09	-0.12	0.02	-0.9	-1.2	0.2
53|51	-0.07	-0.02	-0.04	-0.7	-0.2	-0.4
53|51	-0.34	0.04	0.14	-3.4	0.4	1.4
53|51	-0.14	0.07	0.07	-1.4	0.7	0.7
53|51	-0.04	-0.14	-0.12	-0.4	-1.4	-1.2
53|51	-0.09	-0.14	-0.09	-0.9	-1.4	-0.9
53|51	-0.14	-0.12	0	-1.4	-1.2	0
53|51	-0.21	-0.07	0.02	-2.1	-0.7	0.2
53|51	-0.14	-0.04	-0.07	-1.4	-0.4	-0.7
53|51	-0.17	-0.14	-0.07	-1.7	-1.4	-0.7
53|51	-0.14	-0.19	-0.02	-1.4	-1.9	-0.2
53|51	-0.07	-0.12	-0.04	-0.7	-1.2	-0.4
53|51	-0.02	-0.09	-0.17	-0.2	-0.9	-1.7
53|51	-0.12	-0.02	0.04	-1.2	-0.2	0.4
53|51	-0.12	0	-0.12	-1.2	0	-1.2
53|51	-0.07	-0.07	-0.17	-0.7	-0.7	-1.7
53|51	0.02	-0.04	-0.21	0.2	-0.4	-2.1
53|51	-0.04	0.02	0.04	-0.4	0.2	0.4
53|51	-0.07	0.04	0.04	-0.7	0.4	0.4
53|51	-0.07	-0.02	-0.12	-0.7	-0.2	-1.2
53|51	-0.12	-0.12	-0.17	-1.2	-1.2	-1.7
53|51	-0.17	-0.14	-0.04	-1.7	-1.4	-0.4
53|51	-0.02	-0.14	-0.24	-0.2	-1.4	-2.4
53|51	0.02	-0.04	-0.17	0.2	-0.4	-1.7
53|51	-0.09	0.12	0.12	-0.9	1.2	1.2
53|51	-0.02	0.09	-0.02	-0.2	0.9	-0.2
53|51	0.04	0	-0.17	0.4	0	-1.7
53|51	0	0	-0.04	0	0	-0.4
53|51	-0.02	0.02	-0.09	-0.2	0.2	-0.9
53|51	0	0.04	-0.09	0	0.4	-0.9
53|51	0.12	0.02	-0.12	1.2	0.2	-1.2
53|51	0.09	0	-0.14	0.9	0	-1.4
53|51	0.02	-0.04	-0.04	0.2	-0.4	-0.4
53|51	-0.02	-0.07	-0.02	-0.2	-0.7	-0.2
53|51	-0.02	-0.17	-0.07	-0.2	-1.7	-0.7
53|51	-0.07	-0.34	0	-0.7	-3.4	0
53|51	0.02	-0.48	-0.07	0.2	-4.8	-0.7
53|51	0.12	-0.46	-0.09	1.2	-4.6	-0.9
53|51	0.02	-0.24	-0.04	0.2	-2.4	-0.4
53|51	-0.12	-0.07	0.04	-1.2	-0.7	0.4
53|51	-0.04	-0.09	0.02	-0.4	-0.9	0.2
53|51	0.04	-0.21	-0.07	0.4	-2.1	-0.7
53|51	0.02	-0.26	-0.04	0.2	-2.6	-0.4

53|51	0.04	-0.24	0.07	0.4	-2.4	0.7
53|51	0.02	-0.09	0.12	0.2	-0.9	1.2
53|51	-0.09	-0.04	0.09	-0.9	-0.4	0.9
53|51	-0.14	-0.09	0.14	-1.4	-0.9	1.4
53|51	-0.07	-0.12	0.07	-0.7	-1.2	0.7
53|51	0	-0.04	0	0	-0.4	0
53|51	-0.09	0.09	0.24	-0.9	0.9	2.4
53|51	0.04	0.17	0.17	0.4	1.7	1.7
53|51	0.09	0.09	0.09	0.9	0.9	0.9
53|51	-0.02	-0.02	0.26	-0.2	-0.2	2.6
53|51	-0.04	-0.07	0.19	-0.4	-0.7	1.9
53|51	-0.07	-0.07	0.12	-0.7	-0.7	1.2
53|51	-0.07	-0.04	0.12	-0.7	-0.4	1.2
53|51	-0.04	-0.07	0.02	-0.4	-0.7	0.2
53|51	-0.02	-0.12	-0.04	-0.2	-1.2	-0.4
53|51	-0.02	-0.07	-0.07	-0.2	-0.7	-0.7
53|51	-0.02	0	-0.07	-0.2	0	-0.7
53|51	-0.07	0.02	-0.07	-0.7	0.2	-0.7
53|51	-0.07	0.04	0.04	-0.7	0.4	0.4
53|51	0.02	-0.02	-0.09	0.2	-0.2	-0.9
53|51	0.07	-0.04	-0.09	0.7	-0.4	-0.9
53|51	-0.12	0	0.09	-1.2	0	0.9
53|51	-0.17	-0.02	0.12	-1.7	-0.2	1.2
53|51	-0.02	-0.09	-0.14	-0.2	-0.9	-1.4
53|51	-0.02	-0.21	-0.12	-0.2	-2.1	-1.2
53|51	-0.14	-0.21	-0.02	-1.4	-2.1	-0.2
53|51	-0.07	-0.17	-0.21	-0.7	-1.7	-2.1
53|51	0	-0.09	-0.19	0	-0.9	-1.9
53|51	-0.14	-0.02	0.04	-1.4	-0.2	0.4
53|51	-0.02	-0.04	-0.04	-0.2	-0.4	-0.4
53|51	0.09	-0.09	-0.24	0.9	-0.9	-2.4
53|51	-0.02	-0.04	-0.04	-0.2	-0.4	-0.4
53|51	-0.17	0	-0.04	-1.7	0	-0.4
53|51	-0.04	-0.04	-0.21	-0.4	-0.4	-2.1
53|51	-0.12	-0.12	-0.14	-1.2	-1.2	-1.4
53|51	-0.19	-0.14	0.02	-1.9	-1.4	0.2
53|51	-0.07	-0.12	-0.17	-0.7	-1.2	-1.7
53|51	0	-0.02	-0.24	0	-0.2	-2.4
53|51	-0.04	0.02	-0.07	-0.4	0.2	-0.7
53|51	0	0.02	-0.07	0	0.2	-0.7
53|51	0.02	0	-0.09	0.2	0	-0.9
53|51	-0.21	0	0.02	-2.1	0	0.2
53|51	-0.24	0.02	0	-2.4	0.2	0

53|51	-0.07	-0.04	-0.14	-0.7	-0.4	-1.4
53|51	0.09	-0.07	-0.21	0.9	-0.7	-2.1
53|51	0.04	-0.04	0.12	0.4	-0.4	1.2
53|51	0.02	-0.02	0.02	0.2	-0.2	0.2
53|51	0.04	-0.04	-0.21	0.4	-0.4	-2.1
53|51	-0.09	-0.21	-0.09	-0.9	-2.1	-0.9
53|51	-0.17	-0.43	-0.04	-1.7	-4.3	-0.4
53|51	0.02	-0.65	-0.36	0.2	-6.5	-3.6
53|51	-0.07	-0.63	-0.09	-0.7	-6.3	-0.9
53|51	-0.21	-0.53	0.14	-2.1	-5.3	1.4
53|51	-0.12	-0.41	-0.07	-1.2	-4.1	-0.7
53|51	-0.04	-0.31	-0.17	-0.4	-3.1	-1.7
53|51	0.02	-0.26	-0.02	0.2	-2.6	-0.2
53|51	0.12	-0.19	-0.02	1.2	-1.9	-0.2
53|51	0.07	-0.09	0.02	0.7	-0.9	0.2
53|51	-0.19	-0.09	0.14	-1.9	-0.9	1.4
53|51	-0.24	-0.29	0.14	-2.4	-2.9	1.4
53|51	-0.17	-0.41	-0.12	-1.7	-4.1	-1.2
53|51	-0.07	-0.31	0.04	-0.7	-3.1	0.4
53|51	-0.07	-0.07	0.26	-0.7	-0.7	2.6
53|51	-0.09	0.24	0.29	-0.9	2.4	2.9
53|51	0.02	0.29	0.26	0.2	2.9	2.6
53|51	-0.07	0.26	0.29	-0.7	2.6	2.9

Appendix B
Numerical Simulations; MATLAB Code

```
%% Simulation of Tractor using Passive, Fuzzy-PID and PID
Controller and Compute Spectral Density

% Clear data and figures

clc

clear

close all

warning off

% Define system parameters

% Mass of Vehicle

M=2110;

% Mass of tillage implemented

Mc=100;

% Center of mass from front

a=0.6;

% Center of mass from rear

b=0.4;

% Tillage Cg from center of mass of vehicle

c=0.6;


% Tractor Model Parameters

% Mass of front wheel

mf=40;

% Mass of rear wheel

mr=70;
```

```
% Stiffness of front wheel
Kbf=17000;
% Stiffness of rear wheel
Kbr=20000;
% Dampping of front wheel
Cbf=980;
% Damping of rear wheel
Cbr=1200;
% Stiffness of tyre wheel

Kwf=70000;
Kwr=70000;
% PID Controller Parmeters
kp=100;
ki=20;
kd=50;
% Initialize FuzzyPID Controller state=OFF
state= 0;
% Run Model
data1=sim('Model_Step2019');
% Initialize FuzzyPID Controller state=ON
state=1;
% Run Model
data2=sim('Model_Step2019');
% Run Model with PID Controller
data3=sim('Model_Step_PID2019');
% Tractor displacement
figure
```

```
plot(data1.disp_vehicle,'-b')
hold on
plot(data3.disp_vehicle,'-r')
plot(data2.disp_vehicle,'-c')
grid on
ylabel('Displacement (m)')
legend('Passive','PID Control','Fuzzy-PID Control')
title('Tractor Body Displacement')
% Seat displacement
figure
plot(data1.disp_seat,'-b')
hold on
plot(data3.disp_seat,'-r')
plot(data2.disp_seat,'-c')
grid on
ylabel('Displacement (m)')
legend('Passive','PID Control','Fuzzy-PID Control')
title('Tractor Seat Displacement')
% Seat Velocity
figure
plot(data1.vel_seat,'-b')
hold on
plot(data3.vel_seat,'-r')
plot(data2.vel_seat,'-c')
grid on
ylabel('Velocity (m/s)')
legend('Passive','PID Control','Fuzzy-PID Control')
```

```
title('Tractor Seat Velocity')
% Seat Acceleration
figure
plot(data1.acc_seat,'-b')
hold on
plot(data3.acc_seat,'-r')
plot(data2.acc_seat,'-c')
grid on
ylabel('Acceleration (m/s^2)')
legend('Passive','PID Control','Fuzzy-PID Control')
title('Tractor Seat Acceleration')
%% Power Spectral Density
% For Passive
x=data1.acc_seat.Data;
fs=1/(data1.tout(2)-data1.tout(1));
N = length(x);
xdft = fft(x);
xdft = xdft(1:N/2+1);
psdx = (1/(fs*N)) * abs(xdft).^2;
psdx(2:end-1) = 2*psdx(2:end-1);
freq = 0:fs/length(x):fs/2;
figure plot(freq,pow2db(psdx))
% For PID
x=data2.acc_seat.Data;
fs=1/(data2.tout(2)-data2.tout(1));
N = length(x);
xdft = fft(x);
```

```
xdft = xdft(1:N/2+1);
psdx = (1/(fs*N)) * abs(xdft).^2;
psdx(2:end-1) = 2*psdx(2:end-1);
freq = 0:fs/length(x):fs/2;
hold on
plot(freq,pow2db(psdx))
% For Fuzzy-PID
x=data3.acc_seat.Data;
fs=1/(data3.tout(2)-data3.tout(1));
N = length(x);
xdft = fft(x);
xdft = xdft(1:N/2+1);
psdx = (1/(fs*N)) * abs(xdft).^2;
psdx(2:end-1) = 2*psdx(2:end-1);
freq = 0:fs/length(x):fs/2;
hold on
plot(freq,pow2db(psdx))
hold off
legend('Passive','PID Control','Fuzzy-PID Control')
grid on
title("Power Spectral Density")
xlabel("Frequency (Hz)")
ylabel("Power/Frequency (dB/Hz)")
%% Root Mean Square
% For Passive Model
fprintf('Passive Model\n')
RMS1=sqrt(sum(data1.disp_seat.Data.^2));
```

```
RMS2=sqrt(sum(data1.vel_seat.Data.^2));
RMS3=sqrt(sum(data1.acc_seat.Data.^2));
fprintf('RMS value of seat displacement is %0.6f\n',RMS1)
fprintf('RMS value of seat velocity is %0.6f\n',RMS2)
fprintf('RMS value of seat acceleration is %0.6f\n',RMS3)
% For PID Model
fprintf('PID Model\n')
RMS1=sqrt(sum(data3.disp_seat.Data.^2));
RMS2=sqrt(sum(data3.vel_seat.Data.^2));
RMS3=sqrt(sum(data3.acc_seat.Data.^2));
fprintf('RMS value of seat displacement is %0.6f\n',RMS1)
fprintf('RMS value of seat velocity is %0.6f\n',RMS2)
fprintf('RMS value of seat acceleration is %0.6f\n',RMS3)
% For Fuzzy-PID Model
fprintf('Fuzzy-PID Model\n')
RMS1=sqrt(sum(data2.disp_seat.Data.^2));
RMS2=sqrt(sum(data2.vel_seat.Data.^2));
RMS3=sqrt(sum(data2.acc_seat.Data.^2));
fprintf('RMS value of seat displacement is %0.6f\n',RMS1)
fprintf('RMS value of seat velocity is %0.6f\n',RMS2)
fprintf('RMS value of seat acceleration is %0.6f\n',RMS3)
```

Appendix C
Mode Shapes; MATLAB Code

```
% Given parameters

M = 2110;          % Mass of tractor (kg)

Mc = 100;          % Mass of tillage implement (kg)

a = 0.6;           % Centre of gravity from front portion (m)

b = 0.4;           % Centre of gravity from rear portion (m)

c = 0.6;           % Tillage CG from centre of gravity of
tractor (m)
Mf = 40;           % Mass of front wheel (kg)

Mr = 70;           % Mass of rear wheel (kg)

Kbf = 17000;       % Stiffness of front wheel (N/m)

Kbr = 20000;       % Stiffness of rear wheel (N/m)

Cbf = 980;         % Damping of front wheel (N-m/s)

Cbr = 1200;        % Damping of rear wheel (N-m/s)


% Constructing the mass matrix

M_matrix = [M+Mc, 0, 0;

            0, Mf, 0;

            0, 0, Mr];


% Constructing the stiffness matrix

K_matrix = [0, -c*Kbr, c*Kbr;

            -Kbf, Kbf, 0;

            -a*Kbf, a*Kbf, 0];


% Constructing the damping matrix

C_matrix = [0, -c*Cbr, c*Cbr;
```

```
            -Cbf, Cbf, 0;
            -a*Cbf, a*Cbf, 0];

% Performing modal analysis
[mode_shapes, frequencies] = eig(K_matrix, M_matrix);

% Displaying mode shapes and frequencies
disp('Mode Shapes:');
disp(mode_shapes);
disp('Frequencies (Hz):');
disp(sqrt(diag(frequencies))/(2*pi));
% Mode shapes
mode_shapes = [1.0000, -0.0083, 1.0000;
               0.9917, 1.0000, 1.0000;
               0.3400, 0.3429, 1.0000];

% Plot mode shapes
figure;
subplot(3, 1, 1);
plot(mode_shapes(:, 1), 'o-', 'LineWidth', 2);
title('Mode Shape 1');
xlabel('Mass');
ylabel('Displacement');

subplot(3, 1, 2);
plot(mode_shapes(:, 2), 'o-', 'LineWidth', 2);
title('Mode Shape 2');
```

```
xlabel('Mass');

ylabel('Displacement');

subplot(3, 1, 3);

plot(mode_shapes(:, 3), 'o-', 'LineWidth', 2);

title('Mode Shape 3');
xlabel('Mass');

ylabel('Displacement');
```
